SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

APPENDIX F

ENVIRONMENTAL BENEFITS ANALYSIS

DRAFT Integrated Feasibility Report and Environmental Impact Statement

US Army Corps
of Engineers®
Seattle District

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DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, DC 20314-1000

REPLY TO
ATTENTION OF

CECW-P

NOV 19 2013

MEMORANDUM FOR Director, National Ecosystem Restoration Planning Center of Expertise (ECO-PCX)

SUBJECT: September 9, 2013 ECO-PCX Recommendation for Approval for Single Use of the Environmental Benefits Model in the Skokomish River Ecosystem Restoration Project

1. The Ecosystem Restoration Planning Center of Expertise (ECO-PCX) evaluated the Environmental Benefits Model. The ECO-PCX recommends single-use approval of the model in the Skokomish River Ecosystem Restoration Project (Encl 1).

2. The HQ USACE Model Approval Panel concurs with the recommendation for single use approval made by the ECO-PCX.

Harry E. Kitch

HARRY E. KITCH, P.E.
Deputy Chief, Planning and Policy Division
Directorate of Civil Works

Encl

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SKOKOMISH RIVER ECOSYSTEM RESTORATION PROJECT ENVIRONMENTAL BENEFITS ANALYSIS

Charles Klimas and Brendan Yuill

U.S. Army Engineer Research and Development Center, Vicksburg MS

Nancy Gleason, Charyl Barrow, and Fred Goetz

Seattle District, U.S. Army Corps of Engineers

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SKOKOMISH RIVER ECOSYSTEM RESTORATION PROJECT ENVIRONMENTAL BENEFITS ANALYSIS

1 INTRODUCTION

The U.S. Army Corps of Engineers, Seattle District (Corps) is conducting a General Investigation (GI) to propose alternative plans for aquatic ecosystem restoration in the Skokomish River Basin, Mason County, Washington. That process follows a prescribed series of steps to formulate and evaluate specific proposed measures, and involves working with various local entities and other state and Federal agencies. Ecosystem restoration of the Skokomish River includes multiple potential actions that are intended to improve the condition and function of the river system, with an emphasis on factors that limit anadromous fish reproduction, refuge, and rearing habitat. The proposed restoration measures range from site-specific engineering actions to altering basic ecosystem processes. There are multiple possible combinations of these measures, and it is the responsibility of the Corps to identify the most efficient configuration as the recommended restoration plan. For the Corps' ecosystem restoration mission, the assessment of project alternatives is directed toward quantifying complex environmental benefits. Ideally, the process of assessing alternatives should be sufficiently broad-based that it captures the major ecological implications of proposed project actions, while being easily understood, and producing outputs that can be used in the context of standard planning and decision-making procedures.

The purpose of the Environmental Benefits Analysis described here is to provide quantification of the potential ecological improvement of proposed restoration actions so that the actions can be compared to each other, and to compare alternative suites of actions in the cost effectiveness and incremental cost analysis. This assessment method is structured to address the objectives and limitations of the Skokomish River as defined in the Section 905(b) Water Resources Development Act Analysis Report and as identified in subsequent follow-up planning meetings for this project. It is consistent with guidelines set by the Corps (USACE 1999; ER 1165-2-501).

1.1 STUDY AREA

The study area for the Skokomish River GI is approximately 11 square miles and is limited to the Lower Skokomish River Valley, the floodplain and channel of the lower mainstem and lower South Fork of the Skokomish (divided into five study reaches), and a major tributary, Vance Creek (Figure 1). It specifically excludes the North Fork and areas upstream of the lower valley due to various constraints, but recognizes that many of the problems that afflict the lower river originate elsewhere in the system. The 905(b) report identifies a variety of agencies and other entities (e.g. US Forest Service [USFS] or Tacoma Public Utilities [TPU]) that may have restoration projects underway throughout the watershed to address some of those issues, and specifies that the Corps will coordinate with them.

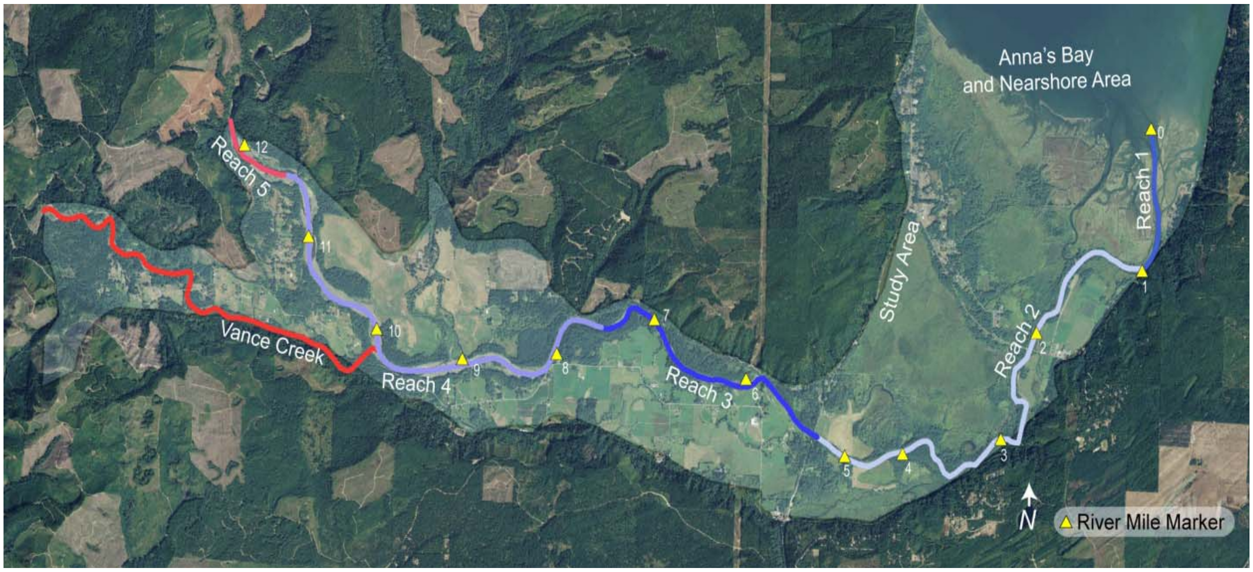

Figure 1. Study Area and Assessment Reaches

1.2 PROBLEM IDENTIFICATION

The Skokomish River Basin was the subject of extensive field investigations beginning more than a decade ago. The Washington Department of Fish and Wildlife and Point No Point Treaty Council conducted habitat assessments focusing on Hood Canal summer chum salmon recovery planning (WDFW and PNPTC 2000), and Correa (2003) described the condition of the area in terms of factors limiting the availability and condition of habitat for all species in the Salmonidae family that are present in the Skokomish basin (Chinook, chum, coho, pink, steelhead, sea run and resident cutthroat, rainbow trout, and bull trout). A more recent study (Peters et al. 2011) revisited the basin and provided a comprehensive characterization of aquatic and riparian habitat conditions. These reports noted that each salmonid species differs in the timing of critical life history events and the way it uses various habitats, but that all of the anadromous fish in the system have the same basic requirements:

- Adequate water quality and appropriate water temperatures;
- Balanced sediment budget;
- Stable spawning gravels;
- Pools and instream structure including large boulders and logs;
- A functional riparian zone;
- Connected freshwater migratory and refuge habitats; and
- A complex of healthy estuarine and nearshore habitats to allow transition from freshwater to seawater.

All of these critical factors were found to be compromised or lacking to some extent. Much of the degradation originates from excess sediments in the channel system, changes in flows, and disconnection of the floodplain and off-channel wetlands by levees.

During the problem identification phase of the feasibility study, the frequent fish stranding that occurs during overbank flows of the Skokomish River was named as a high priority issue. The flood frequency of overbank flow has increased to a return interval of more than once per season, often as many as four times in one winter. The high flow events coincide with the fall migration of Chinook, coho, and steelhead, as well as the incubation of eggs and alevin stage in the redds. The flooding causes adult fish to become stranded in the fields adjacent to the river. For fish that have been able to spawn in the river, the late winter and early spring floods scour the redds causing mortality of incubating eggs, and strand juvenile fish in the fields.

Change in disturbance regime has been identified as an anthropogenic stressor to many salmon populations (Waples et al. 2009). For example, over the past 80 years in the Stillaguamish River, the discharge that had a return interval of 10 to 20 years has become a one- to two-year event (Waples et al. 2008). Seiler et al. (2002) found a strong correlation between high discharge and low egg-to-migrant fry survival. Naturally occurring high flows cause a certain rate of mortality, but viable salmon populations have the resilience to rebuild after loss during rare events. However, the increased frequency from anthropogenic causes may now be too frequent for the salmonid populations to be able to adapt (Waples et al. 2009).

The sedimentation rate in the Skokomish River has exceeded the river's ability to transport sand and gravel, which has led to reduced channel capacity. The river's discharge capacity is now only approximately 25% of the two-year return interval discharge. Flood frequency is multiple times per winter. This flood frequency regime causes such frequent and substantial mortality to the annual returns of migrating salmon that the populations may no longer have the abundance to withstand such losses.

Another characteristic of the Skokomish River is that the variety of habitat types has been significantly reduced mainly by the removal of large wood decades ago, and the filling of pools due to wood removal and excessive sedimentation. This reduction in habitat diversity leads to reduced resilience of the river's salmon populations (Waples et al. 2009).

Table 1. Habitat factors affecting salmonid habitat in Hood Canal Rivers with supporting information. AM is adult migration, S is spawning, I is incubation, R is rearing (WDFW and PNPTC 2000).

Habitat Factors	Impacts to Channel Processes and Summer Chum	Life History Stages	Supporting Literature
Winter high flow	Redd scour through increased sediment transport	I	McNeil 1964, Tripp and Poulin 1986, Thorne and Ames 1987, Nawa and Frissell 1993, Chamberlain et al. 1991, Schuett-Hames et al. 1994, Montgomery et al. 1996
Summer low flow	Prevention or delay of upstream passage, reduction of available spawning area	AM, S	Chamberlain et al. 1991, Johnson et al. 1997
Water temperature	Elevated temperatures impede adult passage, cause direct mortality, and accelerate development during incubation leading to diminished survival in subsequent life stages	AM, SI, I	Beschta et al. 1987, Holtby and Scrivener 1989, Bjornn and Reiser 1991, PNPTC 1998 unpublished data
Dissolved oxygen	Low dissolved oxygen results in direct egg suffocation and diminished survival of subsequent life stages	I	Mason 1969, Koski 1975, Bams and Lam 1983, Chapman 1988, Bjornn and Reiser 1991, Peterson and Quinn 1994b
Fine sediment	Suffocation of developing embryos, entombment of fry in the gravel bed, compaction and cementing of spawning beds	S, I	Koski 1975 and 1981, Chapman 1988, Salo 1991, McHenry et al. 1994, Peterson and Quinn 1994a
Coarse sediment	Channel aggradation leads to egg/fry entombment, redd dislocation	S, I	Madej 1978, Tripp and Poulin 1986
Large woody debris (LWD)	Low levels may increase redd scour, contribute to channel instability, and limit availability of adult holding pools and rearing capacity	AM, S, I, R	Bilby 1984, Sedell and Froggatt 1984, Dolloff 1986, Lisle 1986a and 1986b, Bisson et al. 1987, Bilby and Ward 1989, Montgomery et al. 1995
Channel condition	Reduced holding pool quality and availability renders adults vulnerable to predation/harassment; reduced channel complexity increases frequency and severity of redd scour; limited rearing	AM, S, I, R	Osborn and Ralph 1994, Beschta et al. 1995, Spence et al. 1996
Loss of side channels	Limits adult holding areas, and confines spawning to main channel areas where redds are prone to scour, limits rearing habitat	AM, S, I, R	Sedell and Luchessa 1982, Sedell and Froggatt 1984, Hirshi and Reed 1998
Channel instability	Increased substrate mobility resulting in redd scour/entombment or de-watering of redds	AM, S, I	Nawa and Frissell 1993, Osborn and Ralph 1994, Beschta et al. 1995

Habitat Factors	Impacts to Channel Processes and Summer Chum	Life History Stages	Supporting Literature
Riparian Condition (species composition, age, and extent)	Removal and modification of native riparian forests increases water temperatures, reduces stability of floodplain landforms, and reduces LWD recruitment to stream channels (see above)	AM, S, I	Bisson et al. 1987, FEMAT 1993, Beschta 1995
Floodplain and wetland loss	Concentrates flood flows in main channel, increases peak flow volumes, and results in increased redd scour; loss of wetlands reduce summer low flow volumes (see above)	AM, S, I	Henegar and Harmon 1971, Spence et al. 1996
Fish passage and Access	In-channel structures obstruct or impede adult passage; tidegates/dikes limit juvenile access to rearing and feeding habitats	AM, R	Evans and Johnson 1980, Toews and Brownlee 1981, Furniss et al. 1991

1.3 RESTORATION MEASURES

Initial planning documents (project objectives, constraints, and measures) focus on reversing habitat degradation for the most sensitive species in the Salmonidae family, which is in fact an ecosystem restoration perspective in that the anadromous fish species of the Pacific Northwest depend on essentially all components of their native ecosystem, including patterns of stream flow and sediment deposition, riparian forest distribution and structure, properly functioning wetlands, and the spatial arrangement and interconnectedness of aquatic as well as terrestrial habitats. A comprehensive restoration plan for species in the Salmonidae family, as keystone species, effectively restores habitat and nutrient input for a broad suite of over 130 other native plant and animal species (Cederholm et al. 2000). Restoration planning centered on habitat for the Salmonidae family reinstitutes dynamic processes that tend to maintain ecosystem characteristics, and increases primary production and carbon export. The rationale for employing restoration measures and their corresponding assessment metrics that focus on restoring habitat for the many species of the Salmonidae family is that all watersheds in the Pacific Northwest ecoregion are home to these fish that serve as an indicator of the overall health of not only the aquatic environment where they dwell, but also the connected riparian, wetland, and upland habitats. The assessment approach presented here adopts that perspective and frames restoration measures in terms of their effects on salmonids.

Systemic problems that originate outside of the study area are being addressed using a watershed approach by other entities such as USFS and TPU in areas that are closely tied to their respective missions and in areas where they are the principal land managers. For instance, sedimentation is a significant issue in the South Fork of the Skokomish River Basin. Much of this land ownership is with the USFS and a private company, Green Diamond Timber Company (formerly Simpson Lumber). Green Diamond is addressing sedimentation issues through inclusion of larger riparian buffer areas and limiting the amount of new logging roads through a Habitat Conservation Plan that was developed in cooperation with the Washington State Department of Natural Resources (WDNR). The USFS has developed a restoration plan for the upper basin that includes decommissioning roads, revegetation, replacement of culverts and construction of engineered log jams to trap sediment within the main channel. The study area for the Skokomish GI is downstream of these areas; the Corps recognizes that any restoration activities need to be coordinated with these other watershed improvements.

Most of the restoration measures that have been developed by the Corps and various stakeholders for possible inclusion in this effort are commonly used approaches to multispecies habitat restoration in the region (Beechie et al. 2008, Roni et al. 2008). Reconnection of isolated habitats and floodplains, floodplain and riparian reforestation, and instream habitat improvements are frequently recommended, and are among the proposed measures for Skokomish River restoration. In addition to these typical restoration measures, the Corps has proposed excavating a significant quantity of riverbed substrate to increase flood flow capacity, which would also serve to open blocked tributary mouths. Therefore, the assessment system described here is focused on a specific suite of physical manipulations within the defined study area as they are expected to affect the distribution, availability, and quality of habitats used by anadromous fish for reproduction, refuge, and rearing. Some measures are intended to address immediate critical problems, such as removing barriers to migration, even though channel movement or sediment redistribution may undo the intended effects eventually. These are referred to as the “Base Options” in this document because they are considered the first and most important actions to undertake to address immediate needs. Still other measures, such as reconnecting forested floodplain areas, can be expected to have immediate and permanent effects. These secondary measures are referred to as “Increments” as they will be added on to the Base Options. Measures that involve planting trees will accrue benefits gradually as the planted vegetation matures, but the effects will be permanent, and will eventually replace lost stream processes by contributing large wood to the channel and reestablishing channel dynamics, thus making future direct interventions to improve passage less necessary. When all of these measures are implemented as a coordinated effort across the study area, they constitute a comprehensive ecosystem restoration approach that will benefit a broad suite of terrestrial and aquatic plant and animal species. This process-based restoration serves to restore the typical ecosystem structures of Pacific Northwest river valleys, which in turn supports the valued ecosystem functions and services.

1.4 MODEL APPROACH

None of the models that are Corps-certified or approved for use for assessing restoration effectiveness is appropriate for use in the case of the Skokomish GI study. The Habitat Evaluation Procedures (HEP) (U.S. Fish and Wildlife Service 1980) have been employed in traditional planning studies for decades, but the models available for any species in the Salmonidae family are complex and require highly specific and intensive data collection (e.g., McMahon 1983) that is well beyond the scope of a multi-project planning study. Terrell et al. (1982) acknowledged this limitation and suggested ways to simplify the process, but did not significantly reduce the need for an elaborate and prolonged field data collection program. More to the point, however, the Habitat Suitability Index (HSI) models for salmonid species are highly focused on site-specific in-stream conditions, particularly those affecting spawning. Habitat requirements for the Salmonidae family make a good surrogate for overall ecosystem health only when they reflect the full range of anadromous fish habitat requirements, including off-channel habitats, food web interactions, and spatial relationships among habitats. Clearly, the available HSI models were not developed with that perspective in mind.

A recently proposed restoration prioritization approach, the Biodiversity Security Index (Cole 2010), addresses Corps planning requirements by focusing on the relative scarcity or vulnerability of affected plant and animal species. In the case of the Skokomish GI study, where various federally protected species are affected, this approach would certainly show a strong justification for implementing a restoration effort when compared to other ecosystem restoration proposals elsewhere in the nation where few or no rare species are involved. However, it will not usefully discriminate among any of the project alternatives likely to be proposed for the Skokomish, all of which will positively affect the same group of highly vulnerable species.

Another approach to assessing ecosystem health and recovery is to focus on fundamental processes, such as primary production. Several measures proposed for the Skokomish River include re-establishment of native vegetation across agricultural lands or early-successional communities, which often contain a large component of non-native species. This has beneficial effects not only on a broad suite of fish and wildlife species within the project area, but also on the health of the Puget Sound and marine ecosystems beyond, which receive organic carbon produced in the basin via export by the river. The elevated functionality per unit area of restoration can be directly represented by the differences in primary productivity between native and non-native plant communities. Where pasture (temperate grassland) is restored to palustrine forest or to emergent wetland, and where weedy, non-forested riparian areas (scrub-shrub) are restored to native riparian or palustrine forest, primary productivity can be expected to double or triple (Whittaker 1975). Thus, the restoration effectiveness of those actions can be expressed as the change in productivity multiplied by the area (acres) restored. However, this approach does not adequately capture the other roles played by these native systems in providing critical in-stream refuge habitats, shading and cooling stream systems, initiating and maintaining sediment dynamics, and other elements of a truly ecosystem-based restoration approach. Nor is it applicable to the assessment of restoration measures that do not much affect primary production but address other objectives, such as creation of pool habitats for fish. For the purposes of this project, it is desirable to use reasonably comparable metrics to assess the effects of all of the various proposed restoration measures, which are aimed at holistic ecosystem restoration.

The approach described here is designed to integrate some of the features and advantages of the methods described above without incorporating some of the disadvantages. It takes into consideration the habitat needs of particular sensitive species, the basic productivity and structure of Pacific Northwest native communities, and the fundamental dynamics of stream ecosystems by grouping restoration actions in ways that reflect key ecosystem attributes, such as the connections between aquatic and terrestrial systems. The selected attributes are assessed in a series of stream reaches, which allows recognition of variation in the extent and types of restoration required in different parts of the ecosystem. The response metrics can be considered at various levels of summation, including across all reaches for a particular set of measures, or across all assessment criteria, or both. In this way, the assessment system can be used to identify whether a particular set of measures or alternatives are weaker or stronger than another with respect to any particular critical habitat components, or to identify key spatial gaps in a restoration plan, while also providing the kind of simplified comprehensive “habitat units” that traditionally feed into the Corps planning process.

A major strength of this approach is that it is based on studies and resource inventories in the Skokomish basin and the region that document the past effectiveness of the proposed restoration measures, provide metrics for evaluating the assessment variables, and provide baseline data that can be used to estimate the effectiveness of project alternatives relative to the existing condition. Another advantage is that the basic steps and logic of the approach have a long history of use in the USACE planning process, including ecosystem restoration applications.

1.5 ASSESSMENT METHOD OVERVIEW

This assessment procedure involves comparing the calculated benefits of proposed project alternatives (future with-project) to the future without-project conditions, using information about the baseline condition as a starting point. The period of analysis (i.e. the project life) is 50 years following construction. This assessment method to quantify project benefits has been tailored to the specific types of management measures that have emerged from the plan formulation process. There are several components to the approach:

- Identify the key limiting factors associated with the stream reaches of the study area illustrated in Figure 1.
- Identify assessment metrics to measure success at addressing key limiting factors.

- Identify specific restoration measures and project sites, the areas affected, and applicable limiting factor(s) to evaluate the sites.
- Determine which projects are combinable or mutually exclusive for combining projects into alternative plans.
- Evaluate the existing habitat quality and future without-project habitat quality over the period of analysis (average annual without-project habitat quality), and estimate the average annual with-project habitat quality over the period of analysis for each of the assessment metrics. The difference between the average annual habitat quality with-project and without-project is the average annual habitat quality benefit for each assessment metric.
- Given the impacts of sedimentation on significantly reduced river capacity and frequent fish stranding, determine relative benefits to address either capacity and/or summer low flow conditions.
- Calculate the average annual habitat units (AAHUs) for each project as a function of the change in habitat quality (or average annual habitat benefit) and the area affected.
- Evaluate specific proposed combinations of projects using the gain in AAHUs associated with each project to identify cost-effective ecosystem restoration alternatives that address the complex life history requirements of anadromous species throughout the study area.

These components are described in the following sections.

2 ESTABLISHING EXISTING AND FUTURE WITHOUT-PROJECT AND WITH-PROJECT CONDITIONS AND PRINCIPAL LIMITING FACTORS WITH ASSESSMENT METRICS

Figure 1 illustrates the locations of five mainstem and South Fork Skokomish stream reaches and the tributary Vance Creek. The stream reaches correspond to those established for a comprehensive geomorphological study conducted by the Bureau of Reclamation (Bountry et al. 2009) and can be generally correlated with reach designations used in Correa (2003) and in Peters et al. (2011). Each of these reaches or areas can be characterized in terms of lacking key habitat requirements (including connectivity) that affect various aspects of anadromous fish life stage requirements as identified in the previous comprehensive studies (WDFW and PNPTC 2000, Correa 2003, Peters et al. 2011). For the purpose of this Environmental Benefits Analysis, we have focused on five assessment metrics that have been identified as indicators of limiting factors as discussed below. The assessment metrics included in this report were selected due to 1) their priority among components of the ecosystem that need restoration, 2) their general rating as being in poor condition compared to metrics that were not selected for measurement, and 3) the availability of empirical information on their existing condition. The existing condition information and projections of future conditions form the basis of our future without-project condition, to which proposed actions in the basin are compared to determine if they could have a measurable change to the environment. Table 2 provides a summary of the assessed ecosystem attributes, the types of restoration measures proposed to address deficiencies, the metrics employed to evaluate them, the applicable portions of the study area, and selected pertinent references.

Channel Habitat Quality: This assessment criterion is measured as the total area of channel with complex habitats (LWD, pools, side channels) and with sufficient depth to allow fish migration during the late summer, when flows in the Skokomish River are typically at their lowest point (Skokomish Indian Tribe and WDFW 2010). Proposed measures to address deficiencies in this factor involve direct removal and/or trapping of excess sediments in the system to create pool habitat, and construction of Engineered Log Jams (ELJs) or anchoring large logs with rootwads in various configurations. The ELJs and anchored logs are expected to initiate and maintain channel dynamics that will be self-sustaining. In addition to creating deeper channels, pools, islands, side channels, and other habitat features for some distance downstream, channel migration initiated by ELJs will recruit additional woody material from the banks, which in turn will form new logjams to replace the engineered structures as they deteriorate. Restored channel habitat is considered to include all channel areas likely to be affected by any of these restoration actions, including areas affected by restored channel dynamics well downstream of the sites where specific measures are applied. Channel area is calculated as the total affected channel length multiplied by the average channel bankfull width as scaled from satellite images.

Floodplain Habitat Quality: Natural floodplain features are important components of the fish habitat that serves to represent overall ecosystem health. Floodplain features are typically structurally complex with aquatic connectivity among these features that include abandoned channels, pools, small tributaries and distributaries, oxbows, side channels, and the wetlands and forested areas that export invertebrates and organic material as well as provide direct refuge habitat during high flows. A fully functional riverine system would normally have a mix of these conditions in varying proportions along its length. Conversion of floodplain to urban and agricultural uses tends to eliminate or degrade the access to and quality of these aquatic features. Proposed restoration measures in this category focus on restoring degraded habitats and reconnecting habitats rendered inaccessible due to sedimentation, levees, and similar obstructions. Restored floodplain habitat is defined by the area of reconnected forest and wetlands, reforested floodplain, and restored aquatic habitats within floodplains including their associated buffer zones.

Mainstem River Channel Capacity: Historically, rivers around the Puget Sound basin typically experience overbank flooding once every 1.5 to two years. The many species of the Salmonidae family present in this ecosystem have evolved with this disturbance regime. Excessive aggradation has caused more frequent overbank flooding that has been shown to be harmful to multiple life stages of these fish. A properly functioning hydrologic regime would exhibit the less frequent flooding such that the anadromous fish could successfully spawn within the riverbed and the offspring could survive to migrate downstream to the estuary. Restored channel capacity is defined as achieving at least a 1.33-year return interval to attempt to achieve more than one generation of successful spawning and rearing, and preferably the two-year flow capacity so that multiple generations of fish can begin to rebuild their stocks.

Table 2. Limiting Factors and Associated Assessment Metrics

Limiting Factor	Assessment Metric	Applicable Restoration Measures	Applicability	Reference
Channel Habitat	Pools	Sediment removal and trapping; placement of structures to maintain channel dynamics, scour channels and maintain in-stream habitat complexity	Reaches 2,3,4, 5, Vance Creek	Bountry et al., 2009; Bjornn and Reiser, 1991; Smith, 1973; Stover and Montgomery, 2001
	Woody Debris			
Floodplain Habitat	Riparian Cover	Opening of side channels and tributaries; providing access to existing floodplain forests and wetlands; levee removal; floodplain and riparian reforestation	Reaches 2,3,4,5, Vance Creek	Bountry et al., 2009; Buffington et al., 2002; House and Boehne, 1985; MacDonald and Keller, 1987; McMahon, 1983.
	Connectivity			
Channel Capacity	Flow Capacity	Sediment removal; providing flood storage capacity; providing fish access to large wetlands	Reaches 1,2,3,4	Bountry et al. 2009; Seiler et al. 2002; Beamer et al. 2005

2.1 ESTABLISHING BASELINE CONDITIONS

The starting point for quantifying benefits of restoration actions is to determine the baseline conditions of the study area. For environmental benefits evaluations, it is important to evaluate environmental parameters that are measurable and that change with the proposed alternatives. While it is difficult and costly to measure all parameters that could change with restoration work, it is important to capture a few key indicators that can serve as a proxy for the host of environmental changes that could be expected. This analysis focuses on three limiting factors as those key indicators: floodplain habitat with the parameters of riparian cover and habitat connectivity, main channel habitat with the parameters of large woody debris (LWD) and pool habitat, and in-channel flood flow capacity with the parameter of survival of species in the Salmonidae family from egg stage to migrant fry stage.

2.1.1 Habitat Quality Assessments of the Skokomish River GI Study Area

Following is a review of available references used to determine the quality ratings of the five assessment metrics of riparian zone, LWD, pool frequency, floodplain connectivity, and channel capacity for features of the Skokomish River GI reaches. Specific selections from the reports were used to establish baseline conditions to be able to compare future with- and without-project conditions, and to quantify the Average Annual Habitat Units.

Three primary reports provide assessments of baseline conditions for the Skokomish watershed (see: WDFW and PNPTC 2000, Correa 2003, and Peters et al. 2011). The first two reports were used in developing conservation plans for restoration of summer run chum salmon and for watershed restoration planning in the Hood Canal while Peters et al. (2011) was a habitat assessment study conducted specifically for the Skokomish GI. Table 3 is a summary of the qualitative ratings by habitat factor for the Skokomish River; the results from all reports are discussed by factor below. These reports were used for the habitat quality scores for the first four assessment metrics listed in Table 2 and described in detail in section 2.1.2.

The channel capacity assessment metric was developed through use of a Bureau of Reclamation report on the geomorphology of the Skokomish River (Bountry 2009), and two reports on the effects of channel aggradation in other rivers in the Pacific Northwest. These describe the negative effects of excessive sedimentation and how decades of channel aggradation can decrease survival rate of salmonid eggs to the migrant fry stage (Seiler 2002, Beamer 2005). This is described further in section 2.1.2.5.

Table 3. General rating of impacts to habitat factors and associated habitat quality equivalents in the Skokomish watershed (including all tributaries) affecting chum salmon from WDFW and PNPTC (2000; Table 3.17).

Habitat Factor	Specific Factor	Impact	Habitat Quality Equivalent
Flow	Winter	High	Poor
	Summer	High	Poor
Water Quality	Temperature	Low	Good
	Nutrients/DO	Low	Good
Sediment	Aggradation	High	Poor
Channel Complexity	LWD	High	Poor
	Channel Condition	High	Poor
	Loss of side channel	High	Poor
	Channel instability	High	Poor
Riparian Condition	Species Composition	High	Poor
	Age	High	Poor
	Extent	Moderate	Fair
Floodplain Loss	Floodplain Loss	High	Poor

The WDFW and PNPTC (2000, including 2000a, 2000b, 2000c) report was completed for summer chum salmon recovery planning in Hood Canal; Appendix 3.6 of that report provides watershed descriptions in the basin based on impacts to habitat within those watersheds. Chapter 3.4 is a qualitative description of freshwater habitat conditions in watersheds of Hood Canal and how those conditions were developed, while Appendix 3.7 has specific watershed conditions for the Skokomish River. The report provides a ranking of impacts to habitats critical to various life stages of chum salmon and those impacts are rated low, moderate, and high. Correa (2003) includes a similar habitat rating matrix (Table 16 of that report) that includes a rating system for various habitat characteristics with a range of poor, fair, and good, and areas without data (data gaps), which used various data sources and interpretation by the author or other agency biologists to identify each condition. Additionally, the USFWS completed their own monitoring and evaluation of the Skokomish River and tributaries specifically for the GI but also discussed previous work. The USFWS report (Peters et al. 2011) refers to Correa (2003) in their characterization of the Skokomish River habitat features of interest to the benefits analysis, and used the impact rating established by Correa (2003) to provide the basis for the poor (high impact), fair (moderate impact) and good (low impact) habitat quality rankings.

Peters et al. (2011) described four main effects or threats to juvenile salmon habitat in the Skokomish watershed as the result of the changes in physical process throughout the watershed including 1) habitat availability, 2) habitat connectivity, 3) habitat stability, and 4) habitat quality. The methods used and the locations of study sites for selected habitat features are described in Appendices. The USFWS used standard measurements for habitat conditions, and they created their quality rankings based on Correa (2003). The Correa (2003) report summarizes work from WDFW and PNPTC (2000) with additional input from other agency biologists, but with little mention as to how the results were derived. The WDFW and PNPTC report with various appendices was reviewed to identify information not found in other sources, including an assessment summary of impacts for the Skokomish Watershed habitat conditions (Appendix 3.6), and methods used to gather data for the riparian assessment and other freshwater habitats of the Skokomish found in Appendices 3.7 and 3.8 of that report.

Chapter 3.4 in WDFW and PNPTC (2000) is the freshwater habitat assessment; the methods are described as a compilation of field knowledge of watershed conditions in Hood Canal watersheds to identify factors that were determinants of quality of summer chum habitat. Habitat factors included winter high flow and summer low flow, temperature, nutrient loading, fine and coarse sediment, LWD presence, channel condition, loss of side channels, channel instability, riparian forest size, extent and species composition, floodplain wetland loss, and fish access and passage. These habitat factors were used to determine habitat quality for the following life stages: freshwater migration, spawning, incubation, rearing, and saltwater migration. For each watershed, the biologists as a group rated the condition of each habitat factor according to the severity of impact (none, low, moderate, and high) and identified habitat-related factors for decline (Appendix Report 3.6). Data were used, when available, to rate habitat quality against that found in relatively undegraded basins. Information gaps were filled with the habitat biologists' field knowledge of each basin. Ratings for riparian condition were based on the results of the riparian assessment (Appendix Report 3.7). Appendix Report 3.8 includes a summary of freshwater habitat data and how the data were rated. Background information for the ratings and watershed narratives included State of Washington Timber Fish and Wildlife ambient monitoring data; completed state and Federal (USFS) watershed analyses; and temperature, sediment, and stream discharge data.

2.1.2 References for Quality Ratings of Ecosystem Conditions

The five assessment metrics selected for this model were chosen based on their priority need for restoration in the GI study area. Ecosystem components that are often used as metrics such as water quality and quantity are either rated as good (water quality) or are not a component that the Corps can change as part of the proposed project (water quantity). Table 4 summarizes the baseline conditions as compiled from the major source documents described above in section 2.1.1, as well as the target conditions to be achieved through engineering and design of the proposed project sites.

Table 4. Assessment metrics with parameters measured for baseline condition assessment and target conditions for restoration.

Assessment Metric	Parameters	Baseline Condition (Overall)	Target Condition
Pool Habitat[1]	Number of pools greater than 1-meter depth, good cover, and cool water	Less than 35% of surface area is pool habitat	Pool to riffle ratio of 1:1, or 40-60% surface area in pools
Large Woody Debris[2]	Pieces of LWD per meter of channel length	Less than 0.2 pieces of LWD per meter	75th percentile of natural conditions; 0.6 LWD pieces per meter
Riparian Cover[3]	Species composition, average stand diameter, density, width	High impact (poor) conditions for 62% of the mainstem and 32% of Vance Creek; riparian buffers less than 66 feet wide; 30-70% canopy cover	150-foot riparian buffer width, with 100% canopy cover
Floodplain Connectivity/ Access[4]	Percentage of aquatic habitat remaining connected to the mainstem	General floodplain access has less than 50% connection; certain sites have no connection	100% connection
Channel Capacity[5]	Frequency of overbank flow at specific discharge return interval; fish survival	Overbank flows typically four times per year; correlation between aggradation and reduced egg-to-migrant survival with likely 33% reduction in Skokomish	Two-year flow capacity within bankfull width

[1] Peters et al. (2011)
[2] Peters et al. (2011) and Fox et al. (2003)
[3] WDFW and PNPTC (2000a)
[4] Correa (2003)
[5] Beamer et al. (2005)

2.1.2.1 *Pool Conditions*

Observations made during a July 1998 float trip from the lower end of the South Fork Skokomish River canyon (South Fork RM 3.0) downstream to mainstem Skokomish River RM 4.0 (total distance of nine miles) revealed a lack of pools, long glides, and riffles and a scarcity of wood, particularly large wood and jams (WDFW and PNPTC 2000). Habitat surveys conducted in 1994 in the lower three miles of Vance Creek found 39% pools and a range of 1.5 to 2.6 channel widths between each pool (Skokomish DNR and PNPTC 1994). Because the surveys were conducted when the stream was dry, the data may be skewed (Keith Dublanica, personal communication 1998, cited in WDFW and PNPTC 2000).

Reviewing the description of the mainstem, the Correa report was found to reference the WDFW and PNPTC (2000) report, which relied on that single float trip in 1998 between RM 4 and 9; this showed a general lack of pools upstream of RM 4. The lower four miles of the mainstem were not monitored as part of any previous study so it appears that USFWS (Peters et al. 2011) assumed that reach to be the same as above RM 4. The same table did provide poor pool condition rankings for Hunter, Weaver, and Vance Creeks, good rating for Richert Springs, and data gap for Purdy Creek. Correa (2003) states that an interagency technical advisory group (TAG) rated streams (with no empirical data collected) as follows: 1) Purdy Creek and Hunter Creek can be characterized as one long pool with low habitat quality; 2) Hunter Creek is dredged periodically and acts as one long pool; and 3) Vance Creek was surveyed for pools in 1994 but ratings may be skewed, and the pool quality is reduced to gravel pockets except in a lower stream section with numerous deep pools with adequate cover. Figure 20 in Peters et al. (2011) provides a classification of pool quality in the same reaches with mainstem and tributaries again shown as poor quality. Pool quality was classified as the number of pools greater than 1-meter depth, good cover, and cool water; poor quality as no deep pools; fair with some deep pools; and good with sufficient deep walls. Correa (2003) states, “pool quality is unknown” for the entire lower Skokomish. Site visits conducted by the study team resulted in a consensus that there is a severe lack of pools, and all pools located were deemed poor quality according to the parameters described above.

Peters et al. (2011) created their Figure 19, which shows pool condition defined by percent pool habitat throughout the mainstem, South Fork Skokomish, and several tributaries based on qualitative criteria of poor, fair, and good that they state is modified from Correa (2003). The lower Skokomish and tributaries are shown in the figure as having a poor percentage of pool habitats. Correa (2003) includes a summary table showing all values for pools (percent pools, pool frequency) as “data gaps” with no rating for the mainstem. The quality rankings identified percent pools as poor at less than 35% surface area as pool habitat, 35-50% surface area is fair, and greater than 50% surface area as pool habitat as good.

Peters et al. (2011) described that in their study they measured four metrics to evaluate pool quality, including average thalweg depth, maximum thalweg depth, average residual pool depth, and maximum residual pool depth. They describe that the four metrics allow for comparisons of pool depths to overall reach depths. Overall, they found that deep-water habitats commonly associated with pools made up between 25% and 44% of the habitat. However, deep-water habitats were absent or in low abundance in several study reaches. In addition, deep-water habitats, which are very important habitats during the winter, were in lowest abundance during that period. Based on WDNR watershed analysis indices (WDNR 1997), the habitat quality rating for percent pool (using percent deepwater as percent pools) would be poor for nine of 21 summer sites, fair for six sites, and good for the other six sites. For winter sites, 20 of 23 sites would be rated as poor, two sites would be rated as fair, and one site would be good. The percentage of deep-water habitats tended to be greater in the stream estuary ecotone, tributaries, and the North Fork Skokomish than in the South Fork Skokomish during the summer and greatest in tributaries and the North Fork during the winter (Figure 21 in Peters et al. 2011).

Overall, the percent of the habitat that consists of pools to provide summer and winter rearing habitat for juvenile salmonids is rated as poor in most areas of the Skokomish River. Based on the available data from Peters et al. (2011) for the mainstem and best professional judgment from the TAG for the tributaries, it appears that mainstem and tributary study reaches should be considered as poor quality. Additionally, Skokomish GI technical team members have walked sections of the mainstem river and viewed tributary conditions on multiple site visits with the same general conclusions that there is a severe lack of pools in the mainstem and the pool habitat in tributaries is generally poor quality.

No empirical data collection was conducted for the purpose of this ecosystem benefits model; therefore, a simple metric that does not require extensive fieldwork is needed for this decision-making tool. The simplest metric for calculating pool habitat condition is to estimate the percent surface area that is pool habitat. It has long been held that a pool to riffle ratio of 1:1, or 40 to 60% surface area in pools is considered desirable for salmon spawning and rearing reaches (Needham 1969). All of these ratings indicate a linear relationship between percent surface area in pools and the categorized quality ratings. The pools metric in this model mimics the Habitat Suitability Index for Chinook salmon (Raleigh et al. 1986). The assumption is that even with no pools, there is still water present, and therefore no zero score is possible; likewise, with 100% pool, essentially a lake, there is still usable habitat area. Achieving anywhere within the range of 40 to 60% surface area in pools achieves a score of 1 (Figure 2).

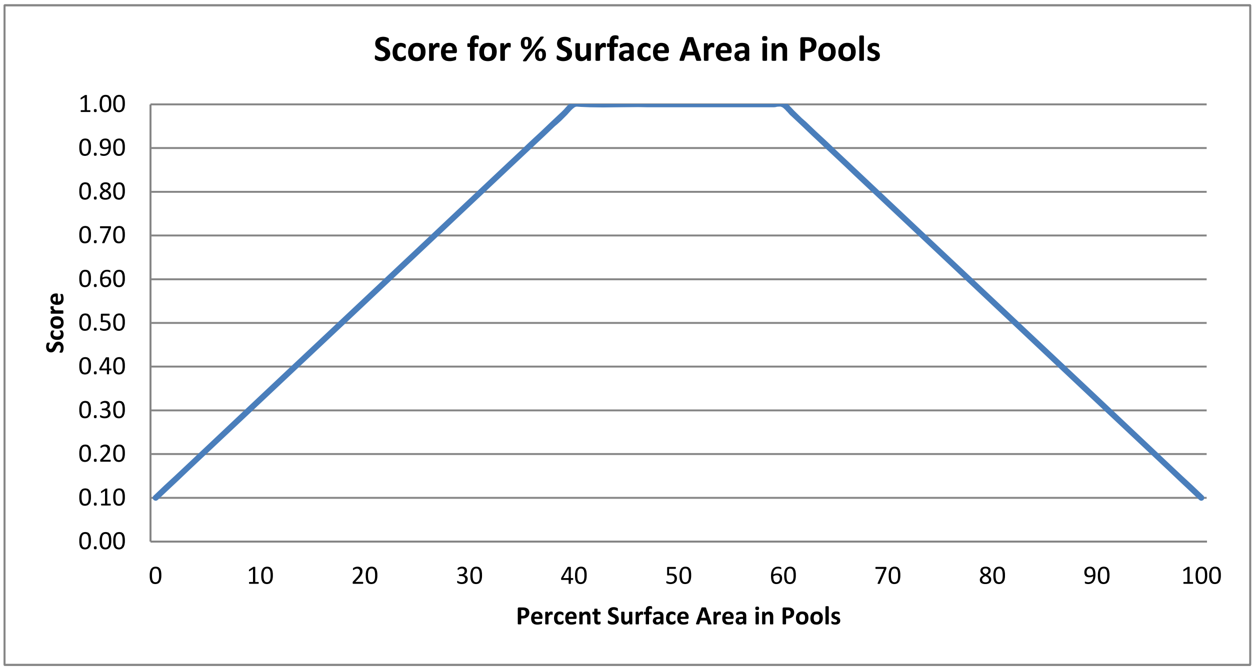

Figure 2. Line graph representing metric score for percent surface area of stream that is in pools.

2.1.2.2 *Large Woody Debris*

Several studies have assessed large wood levels within the Skokomish Basin and have identified reaches where wood levels are below the established standard for undisturbed streams in the Pacific Northwest. Reductions in large wood input to the river channel occur as the active channel width increases. According to WDFW and PNPTC (2000), despite the history of studies in the Skokomish basin, there is little data available on instream habitat for the mainstem and major tributaries to the lower river, although wood loading has been characterized previously as poor in most channel segments (Skokomish DNR and PNPTC 1994; USFS 1995; Simpson Timber Co. and WDNR 1997). Habitat surveys conducted in 1994 in the lower three miles of Vance Creek showed LWD counts ranged from 0.02 to 0.15 pieces of LWD per meter with much of the wood perched above the wetted perimeter, stranded on exposed gravel terraces (Skokomish DNR and PNPTC 1994). Standardized monitoring data has not been collected for the mainstem of the Skokomish River with data limited to observations from a single float trip in 1998, which indicated a scarcity of wood, particularly large wood and logjams (WDFW and PNPTC 2000).

Peters et al. (2011) measured woody debris metrics and attempted to compare those measurements with Fox et al. (2003), who developed recommended large wood quantities and volumes for western Washington rivers (Table 8 in Peters et al. 2011). They determined that large wood was limited in many sites of lower Vance Creek, the South Fork Skokomish, and the mainstem. The number of large debris piles (LDP) per bankfull width was very low for all sites sampled. In particular, the Vance Creek site in this study had no LDP during either summer or winter surveys. Peters et al. (2011) indicated that relative to other fish habitat cover elements, fine wood and vegetative cover were the most common cover elements available in the reaches evaluated, and large wood and large wood debris piles were present at intermediate levels to other cover elements. They did not state how their measurements were broken into quality rankings of low, fair, and good, or how their measurement of LDP could be compared with the work by Fox et al. (2003), who did not use such a metric.

Peters et al. (2011) referenced Correa (2003) in creating their Figure 17, which shows classification levels of LWD, and stating that habitat conditions are poor relative to LWD in the mainstem Skokomish, and Hunter, Weaver, and Vance creeks with the information summarized in the figure. In review of Correa (2003) for the Skokomish GI, it was noted above there has been little or no monitoring of the mainstem and many of the streams, so the rating factor is based on best professional judgment from the author or cooperating biologists (i.e., Purdy Creek has plentiful LWD in the wetland, and upstream of the hatchery, with no wood in ditched areas, [Marty Ereth, pers. comm., 2003]). The quality ratings for LWD were identified as pieces of LWD per meter of channel length with poor defined as less than 0.2, fair 0.2 to 0.4, and good more than 0.4 pieces/m of channel length. These ratings are used for guidance in scoring the LWD assessment metric for this model. Based on Correa's (2003) ratings, the value of LWD in the stream has a linear relationship to the ecosystem benefits score (Figure 3).

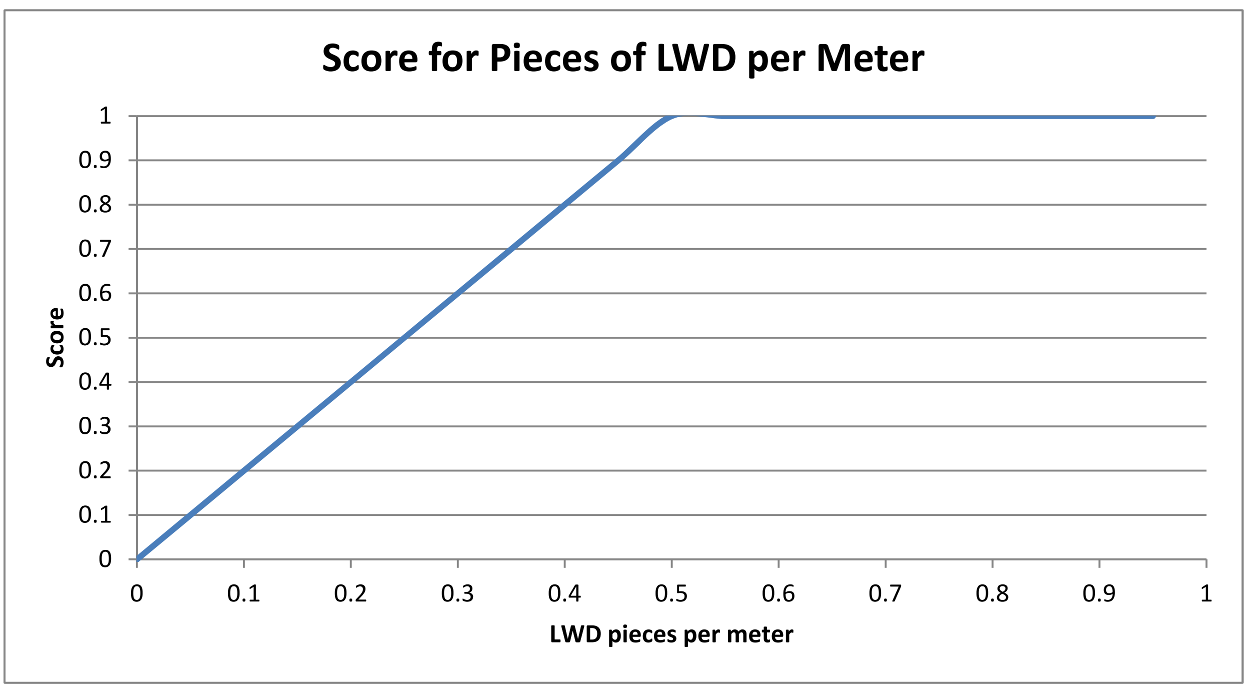

Figure 3. Line graph representing metric score for pieces of large woody debris per meter of channel.

As there are no specific descriptions of quality factors for LWD from USFWS, all reaches in the Skokomish GI benefits analysis should be considered as in poor condition as rated in the other reports unless specifically identified otherwise. Site visits by Corps staff confirmed the conditions are as described in Skokomish DNR and PNPTC (1994) in that there are relatively few pieces and most are perched atop gravel bars and sills, too high to provide in-stream complexity or slower velocity refuge. Riparian plantings implemented for this project would eventually provide recruitment material for in-channel LWD, but this would not be expected to occur until after the 50-year study period. Upstream supply is out of Corps control, but LWD installed as part of the Corps project is expected to accumulate and trap more material. Benefits are only scored for what the Corps plans to install, not for an unpredictable quantity of recruitment. Design guidance provided to the engineers recommends targeting the 75th percentile of natural conditions according to Fox and Bolton (2007); this will result in approximately 0.6 LWD pieces per meter for a score of 1in the future with-project condition.

2.1.2.3 *Riparian Conditions*

In WDFW and PNPTC (2000), Appendix 3.7 describes the methods used to identify impacts to riparian areas in Hood Canal rivers and streams; this level of analysis is not available for LWD, floodplain connectivity, or pool condition. As part of the analysis of habitat limiting factors, aerial photo interpretation was employed to evaluate the condition of riparian forests along summer chum streams in Hood Canal and the eastern Strait of Juan de Fuca. For each segment, the forested riparian buffer width, average stand diameter, species composition, and stand density were noted and the dominant, stream-adjacent land use recorded. They modified the methodology outlined under the Washington State Watershed Analysis Riparian Module to consider both riparian conditions and dominant land use within 200 feet of stream channels. The quality rankings used to evaluate riparian areas are summarized in Table 3.7.1 taken directly from the WDFW and PNPTC (2000) report shown below in Table 5.

WDFW and PNPTC (2000a) describes the Skokomish River (RM 0 to 9) as meeting high impact conditions (poor conditions) for 62% of the mainstem as it is covered by agricultural fields, sparsely vegetated, and/or has a forested riparian buffer less than 66 feet wide. The Vance Creek riparian forest is in better condition overall with 32% as sparsely vegetated or less than 66 feet wide. The majority of Purdy Creek flows through a large intact wetland system, except for the hatchery area above Hwy 101.

Table 5. Summary of riparian assessment impact categories. Riparian buffer density was added to riparian buffer extent to calculate that rating (WDFW and PNPTC 2000, Table 3.7.1).

Riparian assessment category	Low Impact	Moderate Impact	High Impact
Species composition	Conifer dominated (>70% of the canopy)	Mixed conifer/deciduous (both < 70%)	Deciduous dominated (>70% of the canopy) or no tree cover
Average stand diameter	>20 in dbh[1]	12-20 in dbh	<12 in dbh
Density	<33% ground exposure	33-80% ground exposure	>80% ground exposure
Width	>132 ft wide forested buffer	66-132 ft wide forested buffer	<66 ft wide forested buffer

1 dbh, diameter at breast height

Peters et al. (2011) refer to past studies (e.g. Correa 2003) and data collected during their own study that riparian vegetation appears to be degraded within the Skokomish Basin, with the greatest degradation occurring in the lower Skokomish watershed and in mainstem channels relative to tributaries. Correa (2003) provides a habitat rating matrix (Table 16 in that report) that includes a rating system for riparian vegetation (criteria were riparian composition, buffer width, and channel type) for poor, fair, and good, and areas without data (data gaps) that used various data sources and interpretation by the author or other agency biologists to identify a condition. The figure USFWS created (Figure 11 in Peters et al. 2011) appears to have used scores from Table 16 and shows all parts of the mainstem in poor condition as were Weaver Creek, Hunter creek, and the lower South Fork Skokomish (RM 0 to 3). Purdy Creek was classified as poor to good, while Richert Springs was classified as fair to good. In reviewing Correa, the riparian habitat condition described repeats the WDFW and PNPTC (2000) description but includes that Vance Creek had a data gap for riparian conditions. Based on Correa and WDFW and PNPTC reports, the overall riparian condition should be considered poor with greater than 60% of the mainstem having little canopy cover, a narrow buffer, and limited LWD recruitment.

Using USFWS data collected for the GI (Peters et al. 2011), riparian vegetation conditions in the mainstem were described as severely degraded but healthy in other locations. It appears they rated riparian conditions based on percent canopy cover along the bank and in the middle of the channel as measured by their study team. They described that the conditions were based on mature riparian vegetation cover, and that riparian conditions along the banks were most degraded (less than 30% cover) in the Skokomish mainstem from Highway 101 to the confluence with Vance Creek (RM 4.5 to 9.0), in the upper South Fork and in Hunter Creek. Mature riparian cover varied in Vance Creek, McTaggert Creek, and North Fork, and was generally over 70% canopy cover in the lower mainstem below Highway 101 (RM 0 to 4.5). However, in the lower mainstem, riparian cover in the mid-channel islands was less than 30%. An analysis of the rating systems and ranking of habitats found in Peters et al. (2011), WDFW and PNPTC (2000), and Correa (2003), suggest a linear relationship between percent canopy cover and a benefit metric score (Figure 4).

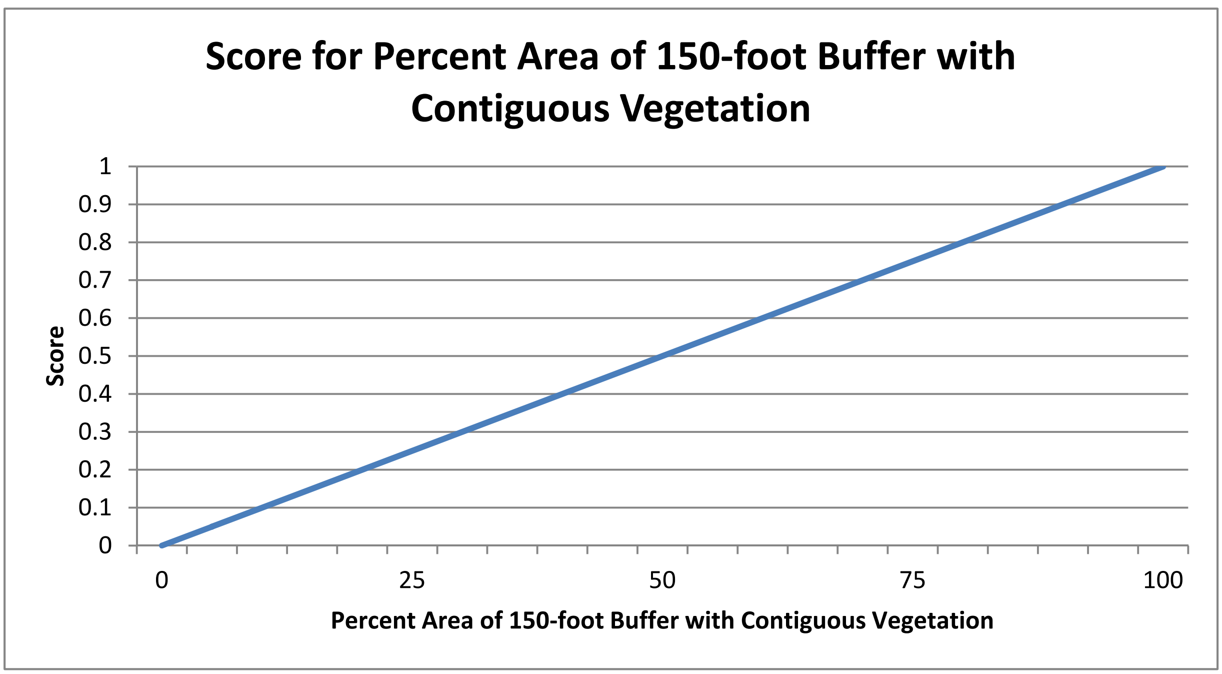

Figure 4. Line graph representing metric score for percent area of 150-foot buffer with continuous vegetation.

The Corps used the following method to calculate the riparian condition metric for existing conditions, and future with-project conditions. Assumptions are that there is a linear relationship between percent canopy cover and the ecosystem benefits score, a target buffer width should be 150 feet for wetlands and stream channels, and that an appropriately detailed assessment can be achieved through aerial photography analysis with calculations in GIS software. The steps are as follows:

1) Identified the seven sites for riparian buffer analysis
2) Created 150-foot individual buffers around each of the sites to be analyzed
3) Within the 150-foot buffer starting at the line representing the project site footprint and extending outward, all contiguous vegetation was identified using one-foot resolution orthophotography that was flown on 22 April 2011. This was done by heads-up-digitizing feature classes that delineated only the contiguous naturally vegetated areas of each site. Natural vegetation versus un-natural vegetation or non-vegetated features were discerned by classifying un-natural as houses, roads, agricultural areas, disturbed ground, fence lines, clear property boundaries, and the border of tree and shrub canopy cover. Grass in residential areas was not counted as natural canopy cover.
4) Calculated the percent area of contiguous vegetation that borders the project footprint by dividing the area of contiguous vegetation by the total buffer area.

The total potential range of this metric is 0 to 100%; the actual calculated percentages for existing conditions are 6 to 81% among the seven project sites that were analyzed. Future without-project conditions are assumed to be the same as existing conditions because land use is not expected to change, and no significant developments are planned for the project sites. To calculate the future with-project conditions, the same steps were applied as listed above with an exception for the assumption that all grass would be planted and all houses, roads, and other unplantable surfaces remained the same. For two of the sites in agricultural fields, it was assumed that the plantable buffer would be constrained at 75 feet instead of 150 due to potential landowner concerns with land use conversion away from agriculture to wetland.

2.1.2.4 *Floodplain Connectivity/Access*

As described in WDFW and PNPTC (2000) and Peters et al. (2011), the majority of the mainstem Skokomish and portions of the South Fork and Vance Creek have been diked and /or channelized, reducing channel complexity and sinuosity, eliminating important side channels, simplifying the remaining habitat, and disconnecting these streams floodplain sloughs and side channels. The mainstem below the confluence is low gradient and has an extensive floodplain. However, the river has been hydraulically disconnected from this floodplain in many areas by levees, bank armoring, channelization, and excessive sedimentation and aggradation (Bountry et al. 2009).

According to Peters et al. (2011; Figure 10, detailed table in Appendix B), loss of floodplain connectivity appears to be worse in the lower watershed than the upper watershed. Further, they reference Correa (2003) to show that habitats in the mainstem Skokomish, the South Fork Skokomish from RM 9.0 to RM 12.0, and Hunter, Weaver, and Vance Creeks are the most degraded, in terms of floodplain connectivity. The mainstem Skokomish River has a hydraulic barrier when a reach goes dry in the summer and an artificial barrier when fish are stranded on the other side of Skokomish Valley Road during winter flooding. In the follow-up review of Correa (2003) for the Skokomish GI benefits analysis, Table 16 in that report shows floodplain access has 50% or more disconnection. The table shows connectivity as good in Purdy Creek and Richert Springs, but more than 50% disconnected in Hunter, Weaver, and Vance Creeks. The report simply describes the majority of the lower mainstem as diked and/or channelized, which disconnected the important side channels and wetlands. Correa (2003, with the data source from

WDFW and PNPTC 2000) described tributary conditions including that 1) Purdy Creek flows through a large intake wetland, although portions of the wetland are isolated by roads, 2) Weaver Creek and Hunter Creek are incised cutting off lower stream sections from the floodplain; and 3) the majority of Vance Creek has been diked and/or channelized, which has eliminated access to important side channels and wetland habitats.

Peters et al. (2011) measured several habitat metrics of the lower Skokomish and noted the severe loss of side channels, mainstem islands, and limited connection of the river to the floodplain, but did not provide an overall ranking for the quality of floodplain connectivity in the mainstem and major tributaries that could be applied to the Skokomish GI benefits analysis. Correa (2003) provided a rating of floodplain connectivity based on what percentage of aquatic habitat in the floodplain has become disconnected. The ratings of percent of aquatic habitat remaining connected to the mainstem in which less than 50% connected warrants a rating of poor, 50 to 90% connected is rated as fair, and 90% or better earns a rating of good indicate a generally linear relationship between percent connectivity and benefits score (Figure 5). The Correa (2003) ranking using the WDFW and PNPTC (2000) data source is used in the assessment of baseline conditions for the Skokomish GI as these reports provide ratings for some of the individual tributaries where projects will occur, or broader river reaches in which the sites lie. To score each project site, either its individual assessment was used, or the general rating from its river reach was used. Connectivity for inlets and outlets described as good in the habitat assessment documents are assumed to be available year round except for in especially dry summers as may occur at intervals greater than two years. For the future with-project score, we assume that project design and construction will result in a site having hydraulic connection year round, again except for unusually dry summer conditions.

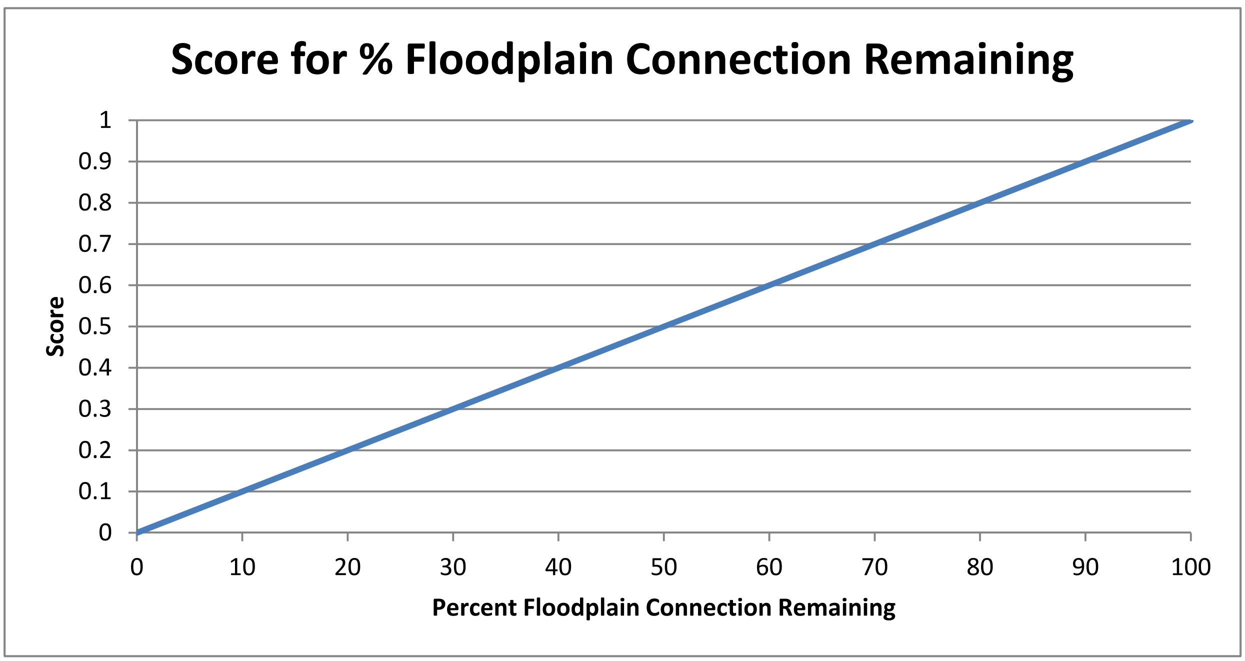

Figure 5. Line graph representing metric score for percent of site or reach with floodplain aquatic habitat connection to mainstem river.

The proposed project sites are completely disconnected, but will become 100% connected after construction. For scoring any other sites, one would assess either the total area of possible connection for wetlands and levee setbacks, or the inlet and outlet for side channels and estimate the percent that has year-round connection along the length of the site or through inlets and outlets as appropriate to the site.

2.1.2.5 *Mainstem River Channel Capacity*

Increased sediment supply and reduced channel capacity negatively affect several anadromous fish life stages. Excess sediment supply in river channels is associated with instability of substrate, which causes scour of redds (eggs in nests) or sediment deposition reducing egg-to-fry survival; it also reduces available rearing and refuge habitat for recently emerged fry and young juveniles. In the Skokomish, the lack of channel capacity for even the one-year return interval discharge causes displacement of fry and juveniles during overbank flows in which they become stranded in floodplain areas without access to return to the river. Those that remain in the channel have little refuge habitat and are therefore forced downstream to the lower river and estuary where they become vulnerable to predators or are unable to survive in saltwater as they have not yet smolted (changed physiology for saltwater life stage). The lack of channel capacity and increased sediment supply result in several impacts to adult salmonids from stranding in floodplain areas. Every year in the Skokomish River, some proportion of the adult salmon runs stray into floodplain areas during overbank flow, and these fish have no return channel to the river (Figure 6). The impacts from this are that the adults may become stranded in floodplain areas where they die before spawning, or they are forced to spawn in areas that become dewatered killing the eggs, or the offspring that do survive in isolated ponds are unable to return to the river to rear.

Figure 6. ESA-listed adult salmon become stranded when overbank flows coincide with spawning migrations.

In natural conditions, rivers of the Puget Sound region see overbank flooding every 1.5 to two years; however, flood frequency in the Skokomish has increased to a return interval of more than once per season. During the problem identification phase of the Skokomish GI, the frequent fish stranding that occurs during overbank flows of the Skokomish River was named as a high priority issue.

The purpose of the channel capacity assessment metric is to quantify benefits of each of the four base options for restoration, because the benefits of these are different from the areas of improved quality as measured by the other four assessment metrics. The benefits are that 1) anadromous fish on their spawning migration would be able to access upstream habitat at the time they arrive, 2) the redds would be less likely to be scoured out due to the gravel instability caused by excessive sediment, and 3) eggs can survive better to the migrant fry life stage.

The scoring for this assessment metric is based on what is deemed natural conditions in Puget Sound area rivers (Figure 7). As stated earlier, rivers around the Puget Sound region typically flood every 1.5 to two years. This is also supported by the substantially improved rate of survival for salmon from the egg to migrant fry stage for which we have data, as well as the assumption that preventing fish stranding mortality will aid in population recovery. These benefits are assumed to have a linear relationship with the improvement in capacity.

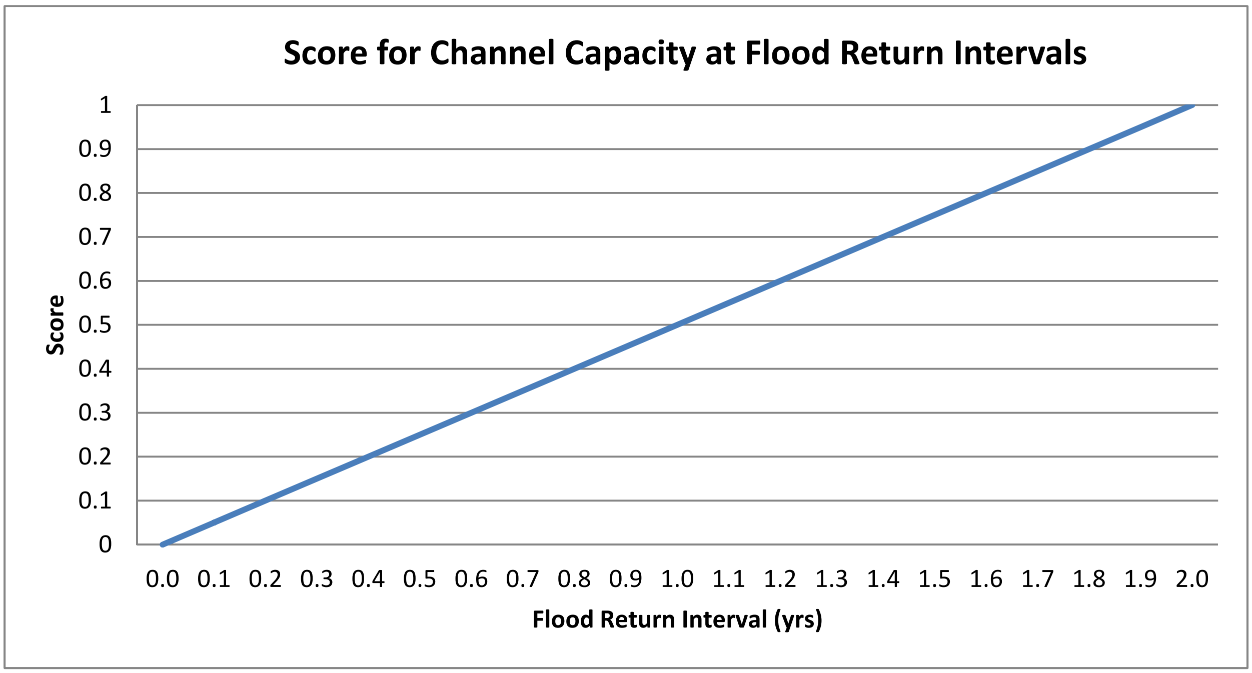

Figure 7. Line graph representing metric score for achieving channel capacity that contains increasing quantities of river flow.

We are assuming the action of removing excess sediment from the channel in combination with the other proposed restoration actions and work by others will restore the Skokomish River mainstem for several decades to a semblance of a functioning river channel. Sediment removal will provide an immediate improvement by increasing the channel capacity while the other proposed project actions will provide increasing benefits as the ecosystem responds to the enhancement features or structure removals, which will improve river and floodplain processes. Targeting a specific flow capacity is recognized as an appropriate goal and the two-year flow, corresponding to typical bankfull width as well as the dominant flow, is often recommended as the target (Copeland and Hall 1998, Millar and MacVicar 1998).

According to Shields et al. (2003), the approach of restoring a river channel to a specific return interval discharge, often corresponding to a two-year return interval as a bankfull discharge, is appropriate when applied to situations with relatively stationary hydrologic conditions. Since the Skokomish floodplain does not have rapidly developing human infrastructure, but is relatively stable as low development and widespread agricultural use, we assume the approach of returning the river to a specific flood flow capacity is appropriately applied.

Supporting information on Salmonid Life Stage of Egg to Fry Survival

The egg-to-migrant fry survival issue supports the target condition of achieving the two-year flow capacity in the mainstem river channel. Data from the Skagit and North Fork Stillaguamish Rivers show that egg-to-migrant fry survival is strongly influenced by peak flow during the egg incubation period and that impairments to watershed processes will decrease egg-to-migrant fry survival of Chinook salmon (Beamer et al. 2005). Seiler et al. (2003) have correlated high discharge with low egg-to-migrant survival with an R^2 value of 0.82. A comparison between functional (natural conditions) and impaired (aggraded) conditions for egg-to-fry-migrant survival is shown in Figure 8 (from Beamer et al. 2005). Although the Skokomish River is in worse condition than other Puget Sound rivers for flood frequency, we believe the reported values are appropriate for the benefits analysis.

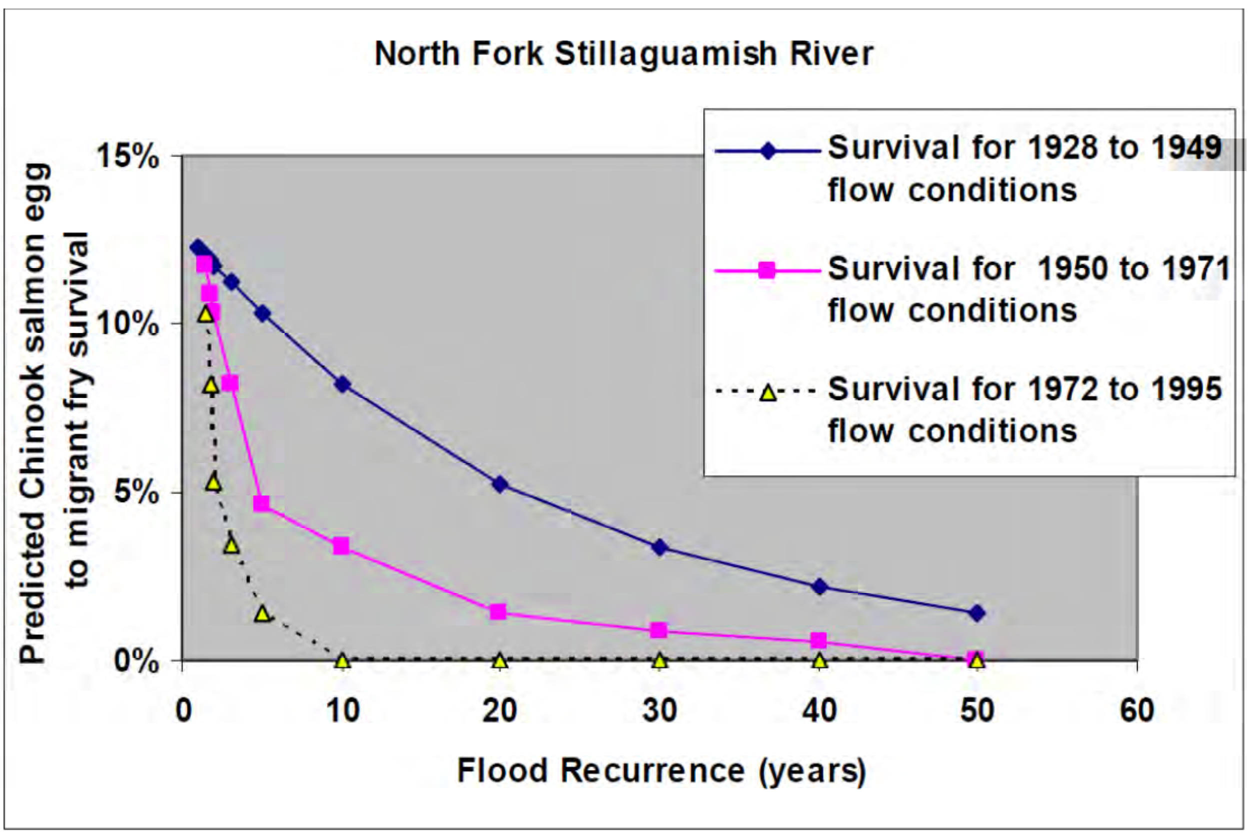

Figure 8. Estimated egg-to-migrant fry survival for the North Fork Stillaguamish River used as a surrogate for Skokomish River chum and Chinook salmon (from Beamer et al. 2005).

Skokomish Chinook salmon spawn in an area over 10 miles long from river mile (RM) 2.2 to RM 12.7; Fall Chum salmon spawn from RM 0 up to RM 11.5 (WDFW 2012).We compared the channel capacity assessment metric to potential increase in egg-to-fry survival using numeric values from Figure 8. While the egg-to-fry survival calculations are not used for the assessment metric, the evidence of improved survival supports the use of channel capacity as a metric and supports the linear relationship between the capacity and the benefits score.

2.2 Determine the Estimated Improvement in Habitat Quality Associated with Each Project

Gains in habitat units associated with projects and specific measures are calculated as Average Annual Habitat Units (AAHUs). They are based on projected changes in habitat quality and affected area, which requires that baseline, future without-project, and future with-project conditions be described quantitatively. This is usually accomplished with an index of habitat quality, where a value of 0.0 indicates that no suitable habitat is available, and an index of 1.0 represents optimum habitat conditions. For the purposes of this environmental benefits analysis, no single index of quality is available or appropriate because of the multiple limiting factors of concern and their varying importance in different parts of the ecosystem. Therefore, multiple indicators have been selected to represent the baseline habitat quality (the existing condition and projected change in habitat quality 50 years into the future over the period of analysis) and to estimate future with-project habitat quality.

As described in section 2.1.1, the indicators used to characterize channel and floodplain habitat quality are derived from the summary data presented in three habitat assessment reports. Figure 9 reproduces an example figure reporting the rating assigned for floodplain connectivity throughout the Skokomish River basin. The study area for this Environmental Benefits Analysis is outlined on that map. Some of the habitat quality ratings are established at the reach scale rather than at the individual project scale. In the example (Figure 9), all of the mainstem, South Fork, and Vance Creek channels are rated "poor" with regard to floodplain connectivity, meaning there is less than 50% connection between the mainstem river and the aquatic habitats in the floodplain.

Each river reach defined in Bountry (2009) and shown in Figure 9 below has roughly the same quality of habitat, so any proposed project increment that is not individually described starts with the same score as the whole reach. All future with-project and future without-project scores are based on the reports as described in section 2.1.2. Personal reconnaissance by project team members verified that the quality ratings for the proposed project sites are not substantially different from the general reach ratings, nor have conditions changed significantly except for the reach that now goes dry during summer low flow. Assessing the habitat quality for each project site would require individual site assessments of significant fieldwork effort, and would very likely result in the same assessment as the previous baseline reports.

The indicators selected to characterize baseline habitat quality are not intended to fully describe conditions in the study area, but rather to represent key elements of habitat structure and dynamics. Additionally, these metrics are ecosystem components that can be affected directly by management measures implementable by the Corps. The assumption is that the condition of those key elements will reflect overall ecosystem structure and function, and that they serve as reasonable surrogates for a broad suite of possible habitat measurements, many of which would be beyond the scope of a planning-level environmental benefits assessment. The indicators used and their scaling and applicability are described below.

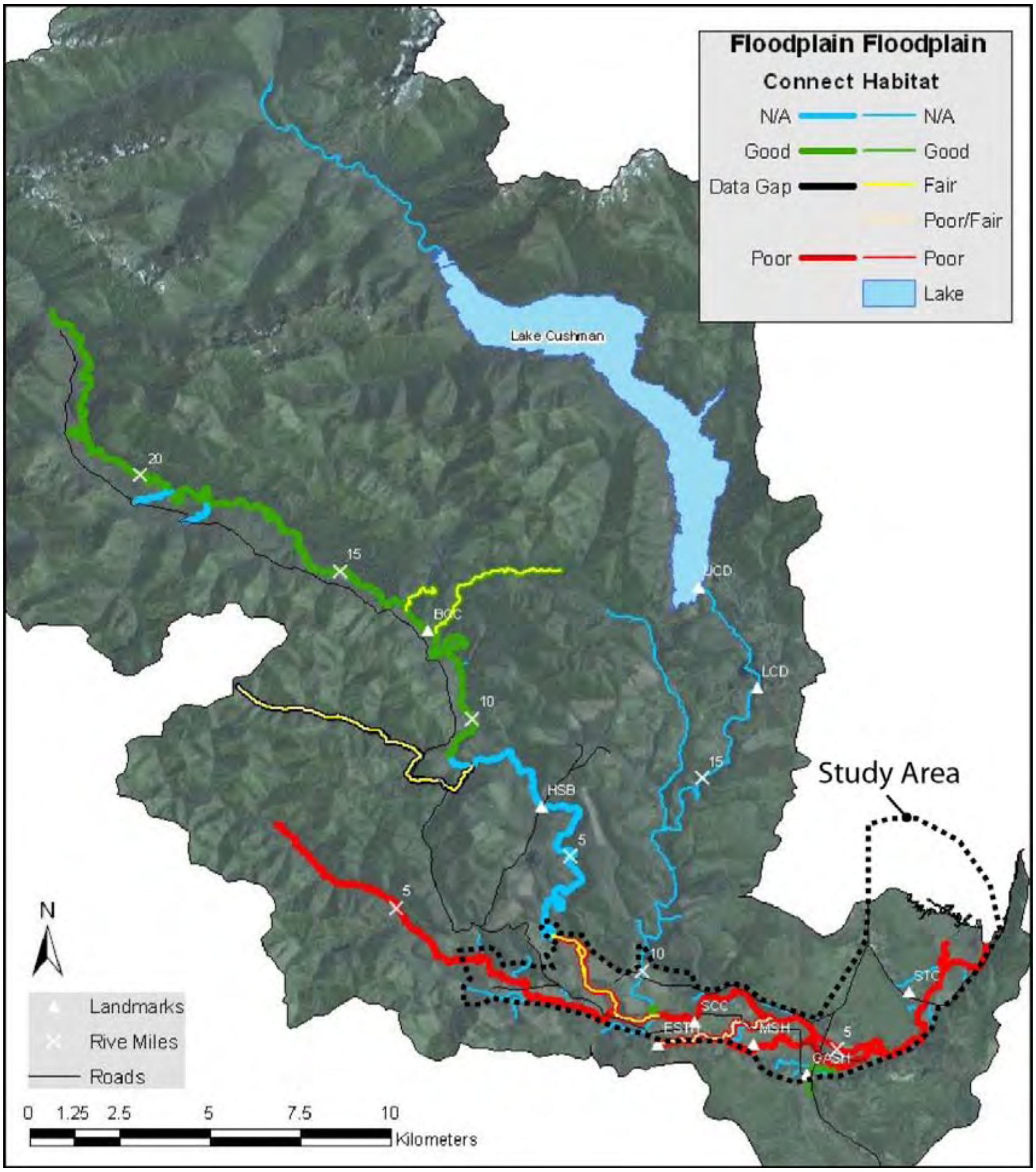

Figure 9. Excerpt from Peters et al. (2011) showing characterization of baseline conditions for floodplain connectivity in the Skokomish basin. GI study area outline added for reference.

Each of the five assessment metrics described in sections 2.1.1 to 2.1.5 use curves to represent the existing and future without-project condition, and future with-project curve. They are projected 50 years into the future over the period of analysis. To estimate the quality achieved at different points in the 50-year period of analysis, it was not possible to rate the individual project sites according to the precise measurement of each assessment metric as this information was not available through the general reach-scale habitat assessments provided in the baseline conditions reports. Each future with-project curve takes into consideration how long a given habitat feature will take to achieve benefits, with a continuous linear function of habitat gain/loss from one notable point in time to the next (i.e. habitat quality is interpolated between these noted points). Habitat quality scores are averaged over the period of analysis to estimate a future without-project (FWOP) and future with-project (FWP) average annual habitat quality index (HQI) score. The difference between the future without-project and future with-project HQI scores is taken as the average annual HQI benefit. Average annual habitat units (AAHUs) are estimated as the product of the affected acreage and the average annual HQI score. This average annual HQI benefit is multiplied by the affected acreage to estimate AAHUs for a given project as shown below.

Average Annual Habitat Units (AAHUs) = Affected Acreage x Average Annual HQI Score

The average annual benefit for a project alternative is the difference in AAHUs from the FWP and FWOP condition for the project's assessment area, as shown below.

Benefits of with project for assessment area (in AAHU) = AAHU (with project) – AAHU (without project)

2.2.1 POOL HABITAT

All riverine life stages of the many salmonid species benefit from abundant pool habitat. Juveniles use pools for a significant portion of their time for feeding and rearing, while adults rest in pools during their arduous upstream migration to spawning grounds. As described in section 1.3 regarding baseline conditions of the Skokomish River, the severe lack of pools is unanimously rated as poor among all entities that have analyzed the river habitat. While the habitat quality rating expresses percent surface area in pools for large reaches of river, the purpose of each assessment metric is to score the change at specific project sites. Therefore, this assessment metric aims to calculate the improvement of percent surface area in pools achieved within each project site's footprint. Each project will be designed to optimize habitat quality. Sediment transport is a very active process in this river with no indication that any reach of the substrate is embedded; therefore, pools are expected to begin developing immediately after construction and especially during the first high water event after construction.

The assumptions for the future without-project time curve are the following:

- we assume that the existing conditions of approximately five percent surface area in pools will remain the same without any manual intervention for improvement
- continued aggradation will likely reduce pool depth, but LWD in the upper watershed may move into the study area and be a countervailing effect. The pools are formed by local hydraulic effects and are not likely to be reduced by the overall deposition trend.
- the severe and obvious lack of pools in the mainstem river is about as poor of habitat as possible; the two large pools identified by study team members appear relatively stable, so we assume conditions are not likely to significantly worsen.

The assumptions that went into the shape of the future with-project time curve are the following:

- based on the supporting literature used to determine the baseline conditions, the mainstem river has only about 5% surface area in pools, so the starting score is 0.21 for any in-channel projects
- floodplain projects have either no pools, or they are characterized as one large pool with no riffle habitat (0% or 100%), therefore their starting score is 0.1;
- pools would be excavated during construction. The target is 40 to 60%; we assume each site will have 30% surface area in pools within 5 years after construction for a score of 0.78;

- habitat-forming processes occur during two-year to 10-year flood events (Knighton 1998), so we assume that at least one of these will occur in the first 10 years and that this will cause the pool habitat to achieve the target of 40% surface area for a score of 1.0 at 10 years;
- pools around LWD will be formed by localized hydraulics; because this is a localized effect, and sediment movement is dynamic in this river, these pools are not prone to as much in-filling from the aggradation effects seen in other areas of the river. Benefits of the new pool habitat will be significant and should be stable for the remainder of the period of analysis, assuming a moderate effort at post-project maintenance.

Figure 10 displays the time curves for the pool assessment metric. These time curves were used to estimate the average annual FWOP and FWP HQI, and the average annual HQI benefit for pools as shown in Table 6.

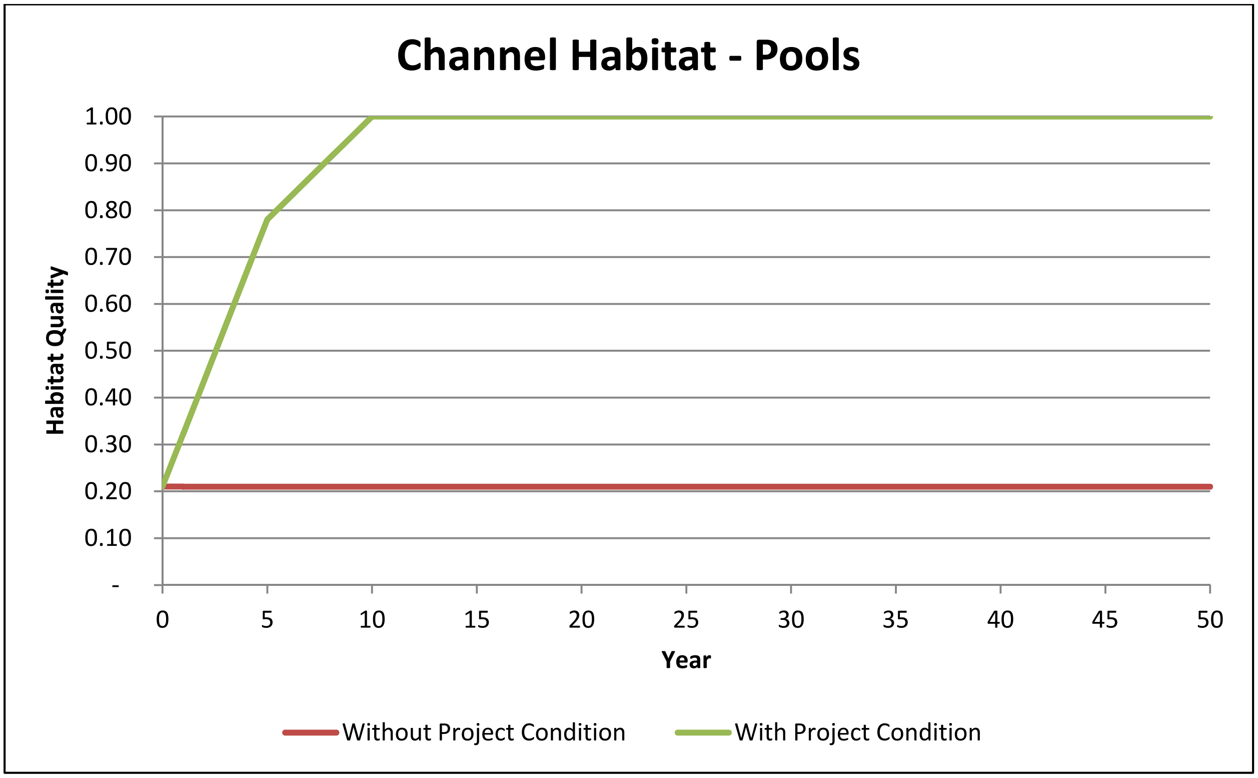

Figure 10. Channel Habitat – Pools: Habitat Quality Index Over Time for Without- and With-Project Conditions

Table 6. Pools Habitat Quality Index Scores for Existing, Without and With Project Conditions, and Average Annual Benefit With Project

Habitat Quality Index Scores - Pools	Score (0-1.0)
Existing Condition	0.21
Average Annual Without Project (Baseline) Condition	0.21
Average Annual With Project Condition	0.93
Average Annual Benefit With Project	0.72

The computations for the without and with project average annual habitat quality scores, and above graph and table are contained in the worksheet ‘Channel – Pools HQI’. The values in this table populate the values in the summary table in the ‘Assessment Metric HQI’ worksheet (see Table 11 in section 2.3).

2.2.2 Large Woody Debris

Large woody debris (LWD) in the active and wetted area of a river channel benefits all life stages of salmonids, but perhaps more so for juveniles as it provides refuge from high velocity flows, cover from predators, rearing area in pools, and surfaces for aquatic insects that become prey items for the juvenile fish. LWD also serves to stabilize substrate and stream banks to prevent too much erosion or instability during the spawning and egg incubation phases. Redd scour from unstable substrate and redd suffocation from bank erosion can be reduced with increased LWD.

Literature on baseline conditions indicates that the quantity of LWD within the wetted channel or low on banks is poor with a count of only 0.06 pieces of LWD per meter. Although there are large logs with root wads present in the riverbed, they are perched high on the gravel bars formed by the excessive sediment in the system.

The assumptions for the future without-project condition time curve are the following:

- LWD is pushed to the channel margins during the numerous floods each year, the logs along the riverbed margins will remain out of reach of average river flows,
- the rate of input from upstream sources will remain the same for the next 50 years as it has been for the past 20 years, which may be biased toward underestimating since forest practices have been improving over the past 20 years and older trees allowed to stand within a buffer zone may be recruited at a higher rate over the next 50 years

The assumptions for the future with-project time curve are the following:

- poor baseline conditions warrant a starting score of 0.1 for 0.06 pieces of LWD per meter;
- construction measures would add the recommended number of key pieces per river mile (Fox and Bolton 2007);
- since LWD exerts its influence nearly immediately, we assume that pieces placed during construction added to material already present in the channel will be actively providing benefits within the first 5 years after construction, for a score of 0.8;
- benefits of bank and substrate stabilization and pool expansion around root wads will continue to accrue at a relatively stable rate. After the 5-year point, we assume that LWD available in the aquatic habitat have recruited additional woody debris and that the restored reaches have accumulated at least the target of .6 pieces per meter for a score of 1.0 by the 10-year mark.
- pool formation around LWD will occur with the first high water flows after construction. Pools around LWD will be formed by local hydraulics and are therefore not as prone to aggradation effects as reaches of the river that have been lacking LWD. We expect the LWD and pools to be self-maintaining for the 50-year study period.

Figure 11 displays the time curves for the LWD assessment metric. These time curves were used to estimate the average annual FWOP and FWP HQI and the average annual HQI benefit for LWD as shown in Table 7.

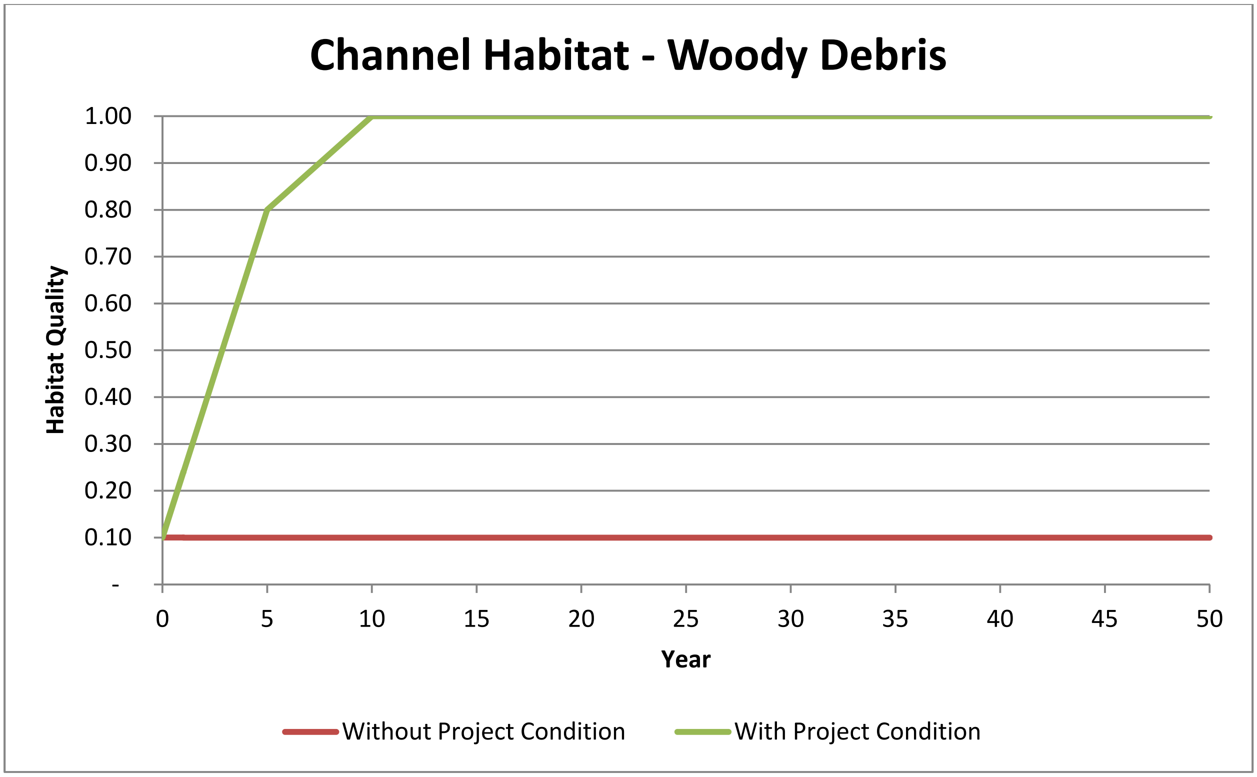

Figure 11. Channel Habitat – Woody Debris: Habitat Quality Index over Time for Without- and With-Project Conditions

Table 7. Woody Debris Habitat Quality Index Scores for Existing, Without and With Project Conditions, and Average Annual Benefit with Project

Habitat Quality Index Scores – Woody Debris	Score (0-1.0)
Existing Condition	0.10
Average Annual Without Project (Baseline) Condition	0.10
Average Annual With Project Condition	0.93
Average Annual Benefit With Project	0.83

The computations for the without and with project average annual habitat quality scores, and above graph and table are contained in the worksheet ‘Channel Habitat – Woody Debris’. The values in this table populate the values in the summary table in the ‘Assessment Metric HQI’ worksheet (see Table 11 in section 2.3).

2.2.3 RIPARIAN COVER

Condition of the riparian zone vegetation is important for overall health of all river ecology and therefore all riverine life stages of salmonids. The recent Skokomish habitat assessments (WDFW and PNPTC 2000, Correa 2003, Peters et al. 2011) use species composition, buffer width, ground coverage, and age, with a resulting rating of the lower mainstem river as poor. Some areas are described as severely degraded while other areas with wide buffers and a high percentage of canopy cover are rated as healthy.

As described in Section 2.1.2.3, the Corps conducted a spatial analysis of the proposed project sites using ArcGIS for the existing conditions and future with-project conditions. Figure 12 shows the existing conditions with the percent of each 150-foot riparian buffer that has contiguous vegetation. Figure 13 shows the future with-project areas that would be planted during construction; we assume achieving 100% canopy cover within all areas that would be planted. Not all areas within the 150-foot buffer of each project can be planted. Areas that are roads, houses, or otherwise non-plantable are assumed to remain in that condition. For the two sites that occur in agricultural fields, we assumed buffer size would be limited to 75 feet surrounding the project footprint as these are on private property and landowner willingness to convert agriculture to wetland is unknown at this time.

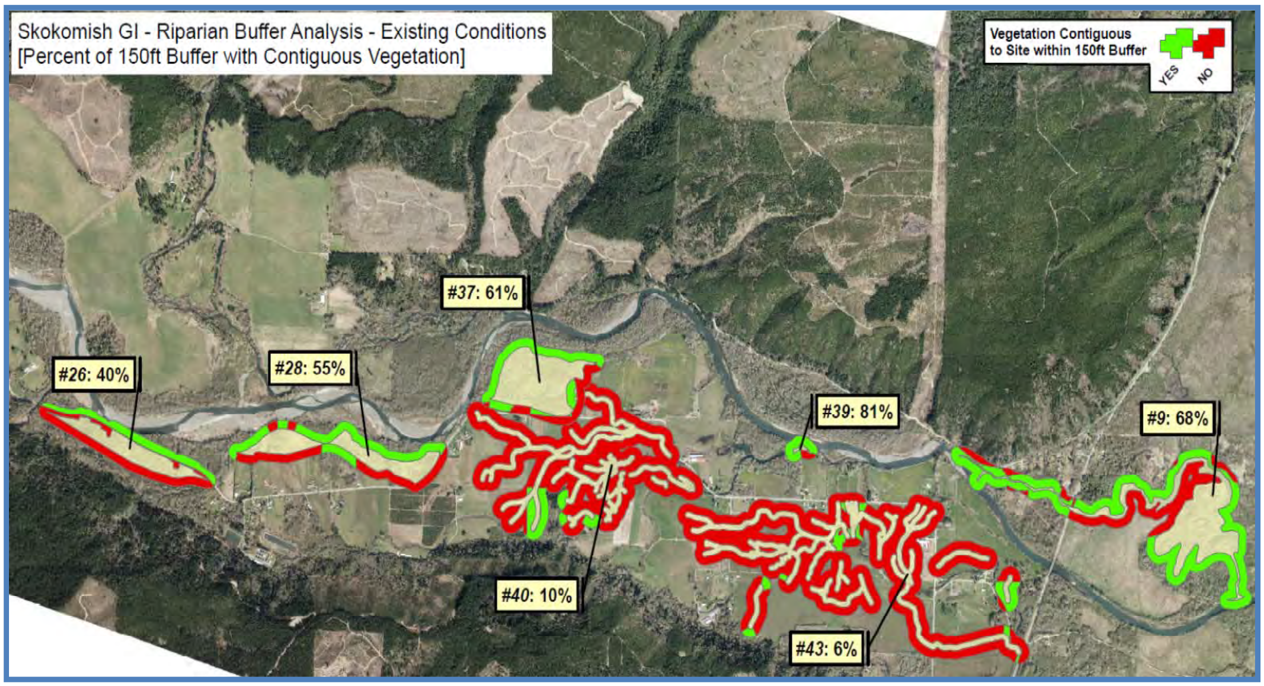

Figure 12. Existing conditions of 150-foot riparian buffer at proposed project sites.

The assumptions for the future without-project condition time curve are the following:

- present land uses would remain the same at each project site, so each site uses the existing conditions score as derived from the spatial analysis
- the present density of canopy cover as viewed in the aerial photographs has reached its full maturity and is not likely to become significantly more dense over the next 50 years, which may be biased toward overestimating present vegetation and underestimating future vegetation.

The assumptions for the future with-project condition are the following:

- the starting score for the time curve is derived from the spatial analysis for existing conditions;
- construction measures that open stream channels for fish access to forested and shrubby wetland areas provide immediate benefits associated with healthy riparian zones as fish access is restored;
- new plantings will be implemented across as much of the plantable area as possible at a density of four to six feet on center for shrubs and 10 to 12 feet on center for trees. Sites are near the river, so recruitment of cottonwoods and alders is expected.
- plantings would have approximately 10% canopy cover immediately after construction, around 80% canopy cover at five years after construction, and are expected to have 100% canopy cover at 10 years after construction.

Figures 14-20 display the time curves for the riparian assessment metric for each of the assessment areas with floodplain habitat limiting factors. These time curves were used to estimate the average annual FWOP and FWP HQI, and the average annual HQI benefit for pools as shown in Table 8.

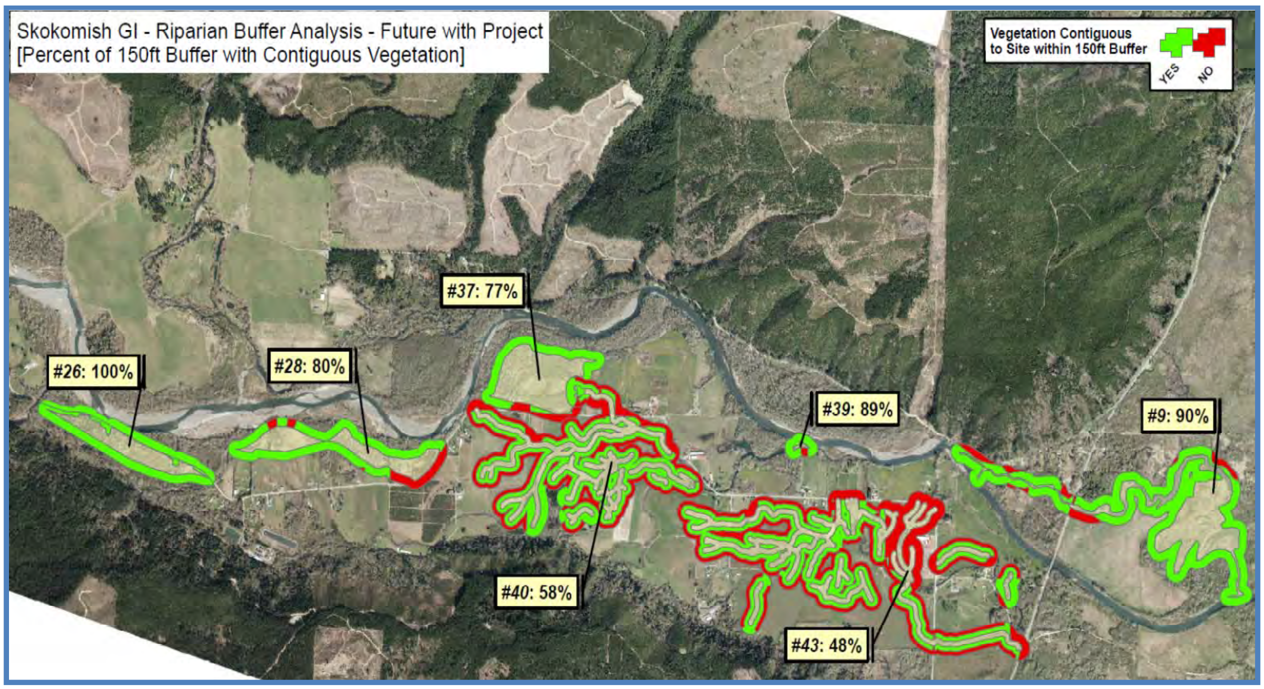

Figure 13. Future with-project conditions of 150-foot riparian buffer at proposed project sites.

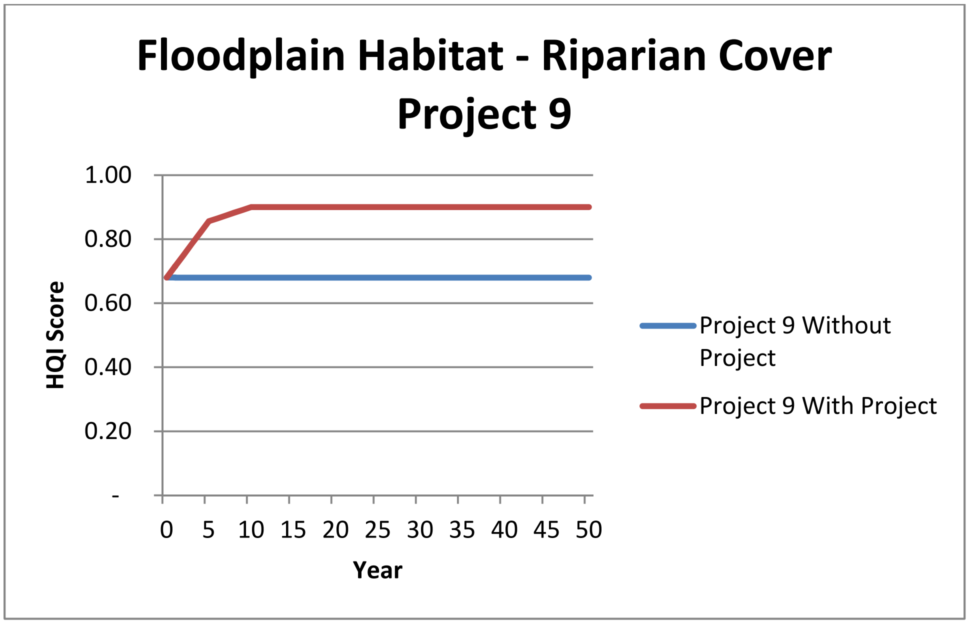

Figure 14. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 9

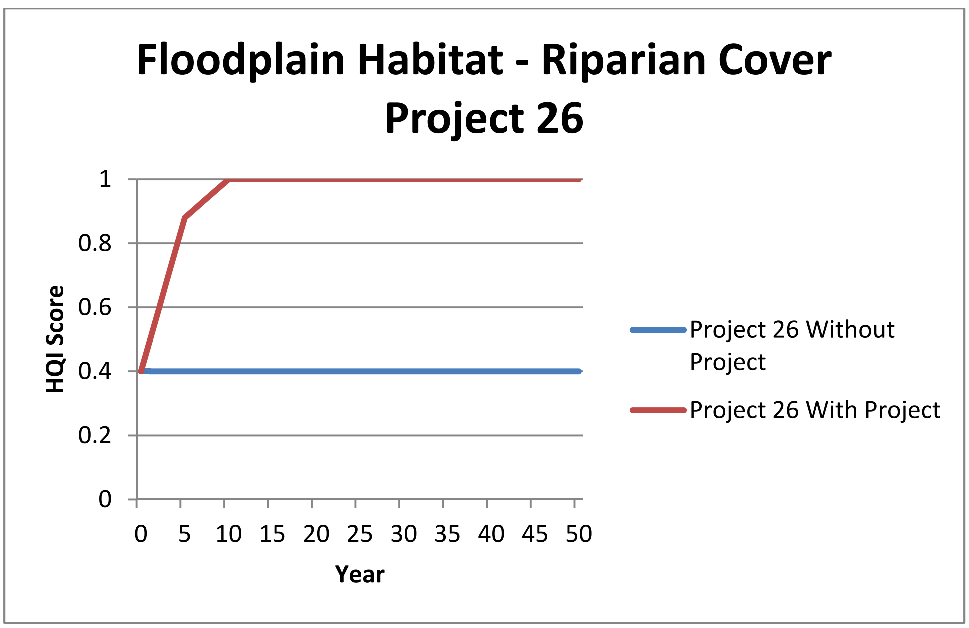

Figure 15. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 26

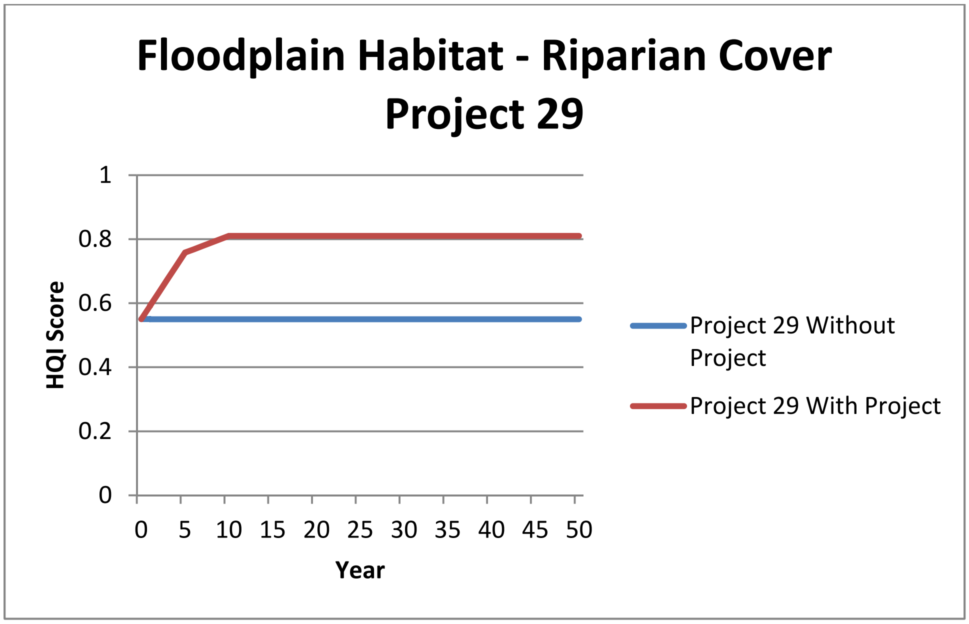

Figure 16. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 29

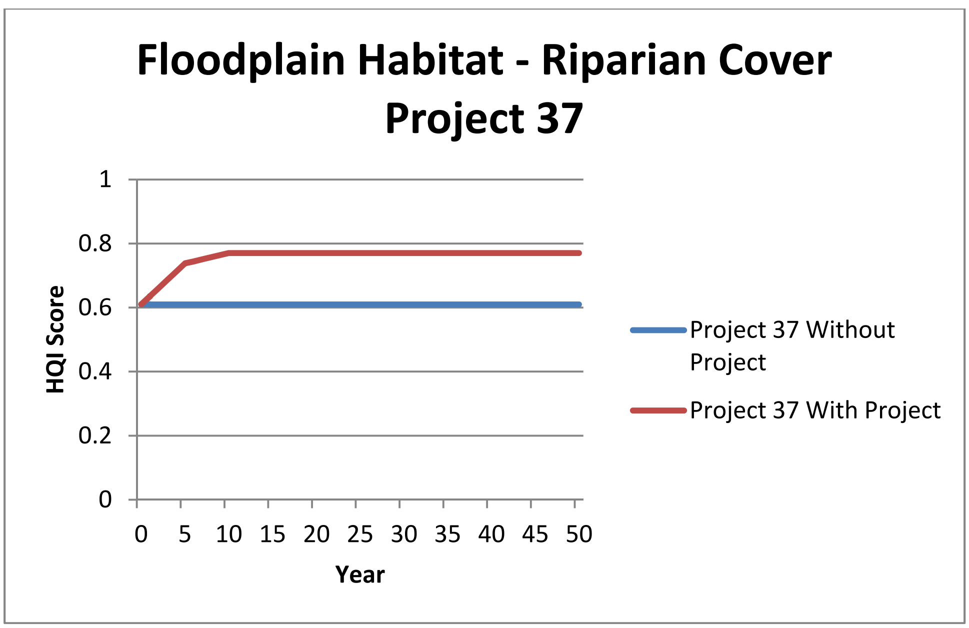

Figure 17. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 37

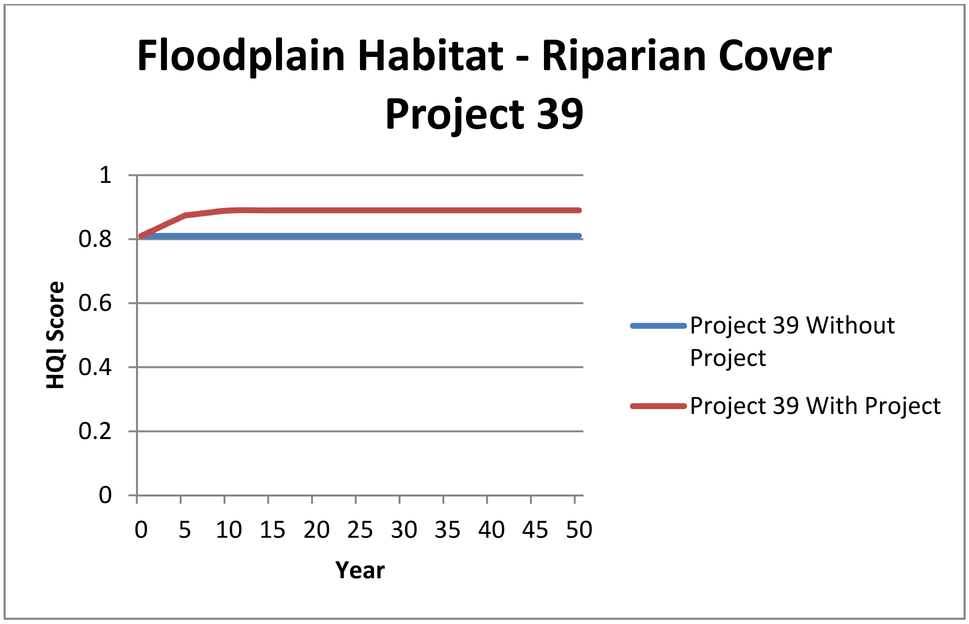

Figure 18. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 39

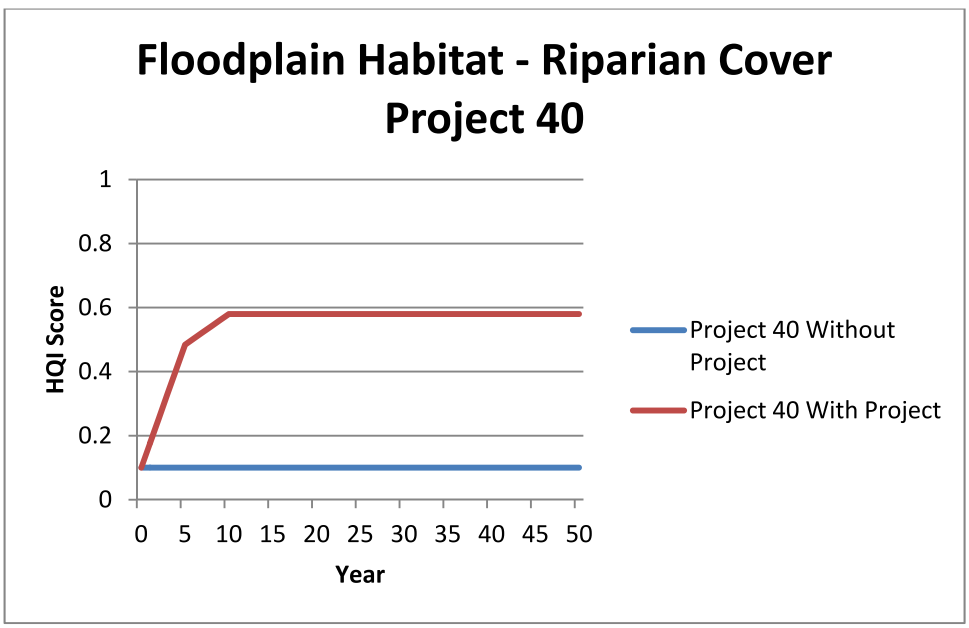

Figure 19. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 40

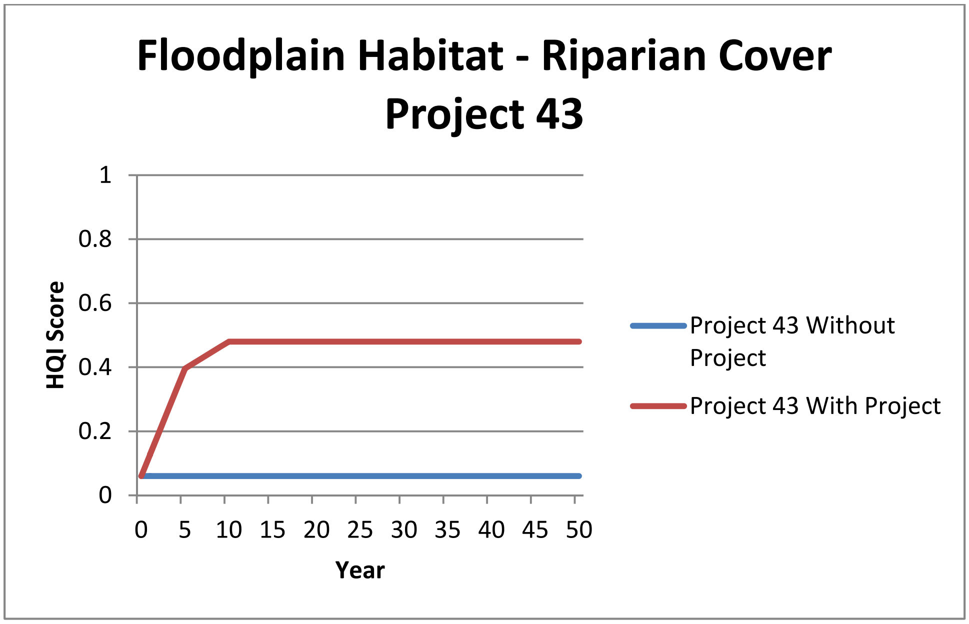

Figure 20. Floodplain Habitat – Riparian Cover: Habitat Quality Index Over Time for Without and With Project Conditions by Project Assessment Area, Project ID 43

Table 8. Riparian Cover Habitat Quality Index Scores for Existing, Without and With Project Conditions, and Average Annual Benefit With Project by Project Assessment Area

Habitat Quality Index Scores – Riparian Cover	Project ID						
	9	26	29	37	39	40	43
Existing Condition	0.68	0.40	0.55	0.61	0.81	0.10	0.06
Average Annual Without Project (Baseline) Condition	0.68	0.40	0.55	0.61	0.81	0.10	0.06
Average Annual With Project Condition	0.88	0.95	0.79	0.76	0.88	0.54	0.45
Average Annual Benefit With Project	0.20	0.55	0.24	0.15	0.07	0.44	0.39

The computations for the without and with project average annual habitat quality scores, and above graph and table are contained in the worksheet ‘Floodplain – Riparian Cover’. The values in this table populate the values in the summary table in the ‘Assessment Metric HQI’ worksheet (see Table 11 in section 2.3).

2.2.4 Floodplain Connectivity

Loss of connections between tributaries, wetlands, off-channel ponds, and secondary side channels have resulted in a rating of poor for habitat conditions in the low-gradient mainstem Skokomish floodplain area. This affects all riverine life stages of salmonids due to the reduction of available spawning, incubation, rearing, and over-wintering habitats. This disconnection is caused partly by diking and draining, as well as the excessive sedimentation that has cut off the mouths of tributaries such that fish passage is blocked.

The assumptions for the future without-project condition time curve are the following:

- Correa (2003) recorded that each of this study's proposed floodplain restoration sites is disconnected,
- reconnaissance through some of the study team's site visits verified that creek mouths may be blocked during summer low flow
- this condition is expected to continue to as sediment continues to accumulate and block channels, and because the present land uses are expected to endure.

The assumptions for the future with-project are the following:

- existing conditions documentation states that the specific proposed project sites are disconnected for fish access from the mainstem river, so the starting point for the time curve is a score of 0;
- construction measures will include removing blockages at tributary mouths, opening fish passage and flowing channels through wetlands, ponds, and secondary side channels, and setting back levees providing immediate access and benefits
- we assume that within five years after the re-connection occurs during construction, the habitat will be 100% connected for a score of 1 because of high water events positively affecting the new connected habitat and the ancillary benefits accruing within five years of the re-connection.

Figure 21 displays the time curves for the connectivity assessment metric. These time curves were used to estimate the average annual FWOP and FWP HQI, and the average annual HQI benefit for connectivity as shown in Table 9.

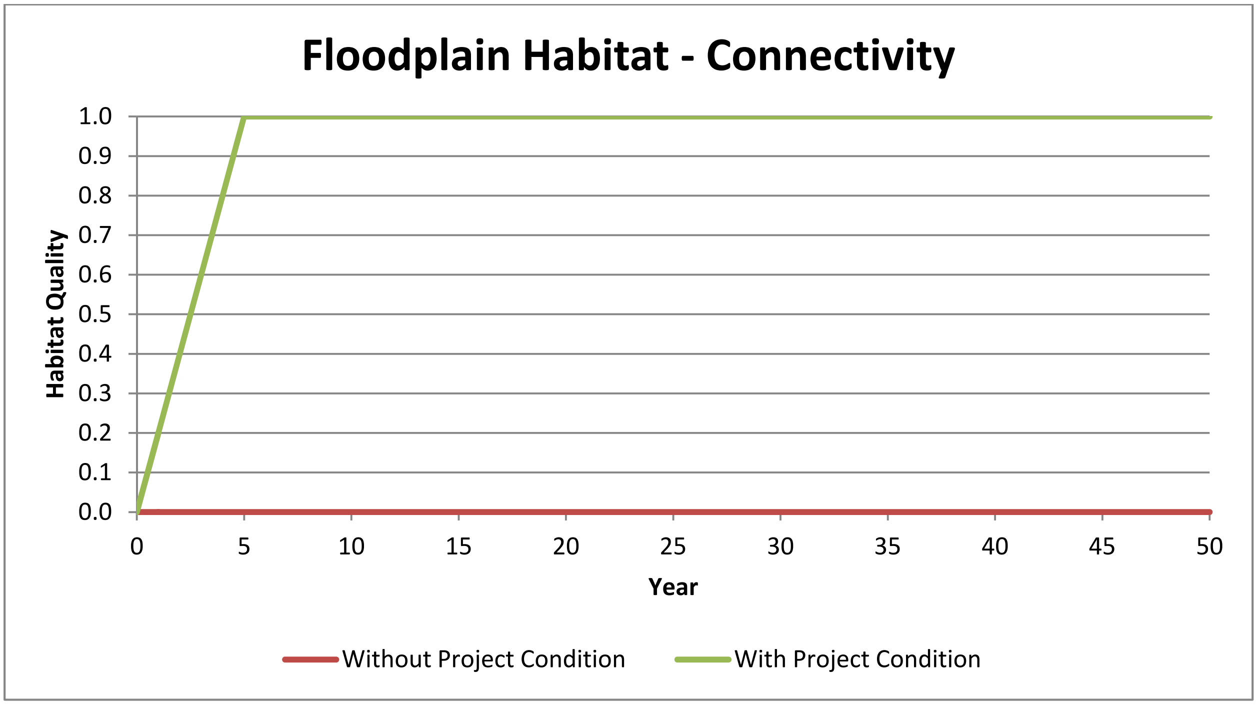

Figure 21. Floodplain Habitat – Connectivity: Habitat Quality Index over Time for Without and With Project Conditions

Table 9. Connectivity Habitat Quality Index Scores for Existing, Without and With Project Conditions, and Average Annual Benefit With Project

Habitat Quality Index Scores - Connectivity	Score (0-1.0)
Existing Condition	0
Average Annual Without Project (Baseline) Condition	0
Average Annual With Project Condition	0.94
Average Annual Benefit With Project	0.94

The computations for the without and with project average annual habitat quality scores, and above graph and table are contained in the worksheet 'Floodplain – Connectivity'. The values in this table populate the values in the summary table in the 'Assessment Metric HQI' worksheet (see Table 11 in section 2.3).

2.2.5 Channel Capacity

Based on the information presented in section 2.1.2.5 regarding potential benefits to salmon from reducing flood frequency, this assessment metric was developed to show relative benefits of one base alternative plan to another. The two-year flood recurrence interval was considered for this analysis because this capacity could have many benefits on the fish populations due to reduced fish stranding.

Another reason for selecting the two-year flow capacity is based on written records of flooding in the Skokomish valley summarized in a USACE report on flooding and sediment baseline conditions (USACE 2011). According to local records, flooding occurred annually in the early part of the 1900s at flows of roughly 13,000 cubic feet per second. Significant logging had already occurred along the South Fork Skokomish with bed elevation decreasing there while aggradation was occurring during the same period downstream from there in the mainstem (Stover and Montgomery 2001). As documented in Stover and Montgomery (2001), review of aerial photographs and meticulously kept U.S. Geological Survey (USGS) records reveals potential causes of changes in channel width and bed elevation over their study years of the 1930s to the 1990s. These USGS records show periods of significant aggradation paired with evidence of specific land use management activities. The target capacity of 17,000 cfs corresponds to approximately a two-year flood return interval, and is likely the approximate capacity that the river contained prior to significant human manipulation of the surrounding watershed. Furthermore, the typical return interval at which low gradient, pool-riffle Puget Sound area rivers experience bankfull discharge in natural conditions is the 1.5 to two-year return interval (Buffington et al. 2003); therefore, this seems to be a reasonable target.

Not all base alternatives achieve two-year capacity, rather they address capacity on a smaller scale, or they only address summer low flow concerns near the confluence where flow goes subsurface in the summer and fish are not able to access habitat upstream. Other capacities were considered but not evaluated due to the cost prohibitive nature of the sediment removal for greater capacities and disruptions to any existing habitat in the Skokomish River.

The Skokomish River typically floods an average of four times each winter, so the flood return interval is 0.25. This corresponds to a score of 0.125 (rounded to 0.13 in Table 10 below) according to the metric devised for benefits calculation. At the current rate of aggradation, frequency of flooding is expected to worsen to a condition in which the river is almost constantly avulsing.

Table 10. Flow Capacity Habitat Quality Index Scores for Existing, Without and With Project Conditions, and Average Annual Benefit with Project

Base #	Existing Habitat Quality Index Score	Average Future Without-Project (FWOP) Habitat Quality Index Score	Average Future With-Project (FWP) Habitat Quality Index Score	Average Change in HQI from FWOP to FWP
1 and 5	0.13	0.03	1.00	0.97
2 and 3	0.13	0.03	0.50	0.47

The average future without-project score is anticipated to be lower than the existing conditions as sediment continues to accumulate and the problems identified with channel capacity become worse. The assumptions for the projection of future without-project are based on the following information:

- Channel aggradation would continue with a sediment input rate of approximately 30,000 to 40,000 cubic yards per year
- Aggradation is expected to cause a major channel avulsion within the next 20 years. The most likely location for an avulsion is near the old North Fork confluence. The river could divert either to the north or to south sides at this location. A diversion to the south would send the river on a five-mile path across agricultural fields to rejoin the existing channel near RM 3. An avulsion is also possible near RM 3.5, where the river could be diverted into the wetland on the north side of the river.

- The wide, shallow river channel will continue to provide poor pool and riffle conditions necessary for spawning.
- Unstable riverbed conditions will continue to disturb spawning sites by scouring redds and reducing the survival of emergent fry.
- Future sediment deposits may have a smaller grain size distribution that includes an increasing amount of fines, reducing the suitability for salmon spawning.

2.3 Summary of Limiting Factor Assessment Metric Habitat Quality for Existing, FWOP, and FWP Conditions

Table 11 summarizes the existing, FWOP, and FWP HQI scores, and the average annual HQI benefit for each of the limiting factors. This table is contained in the 'Assessment Metric HQI' worksheet and is populated from computations of the individual assessment metric worksheets ('Channel Habitat – Pools', Channel Habitat – 'Woody Debris', 'Floodplain – Riparian Cover', and 'Floodplain – Connectivity'. This table is used to lookup average annual HQI benefit scores for benefit evaluation computations in the 'CEICA INPUT DATA' worksheet of the model.

Table 11. Average annual habitat quality index ratings assigned to channel and floodplain limiting factors for existing, future without-project and future with-project conditions, and net difference (average annual HQI benefit).

Limiting Factor	Assessment Metric	Base	Project ID	Existing Habitat Quality Index (HQI) Score	Average Annual FWOP HQI	Average Annual FWP HQI	Average Annual HQI Benefit
Channel Habitat	Pools	all	N/A	0.21	0.21	0.93	0.72
	Woody Debris	all	N/A	0.10	0.10	0.93	0.83
Floodplain Habitat	Riparian Cover	all	9	0.68	0.68	0.88	0.20
		all	26	0.40	0.40	0.95	0.55
		all	28	0.55	0.55	0.79	0.24
		all	37	0.61	0.61	0.76	0.15
		all	39	0.81	0.81	0.88	0.07
		all	40	0.10	0.10	0.54	0.44
		all	43	0.06	0.06	0.45	0.39
	Connectivity	all	N/A	0.00	0.00	0.94	0.94
Channel Capacity	Flow Capacity	1	N/A	0.13	0.03	1.00	0.97
		2	N/A	0.13	0.03	0.50	0.47
		3	N/A	0.13	0.03	0.50	0.47
		5	N/A	0.13	0.03	1.00	0.97

3 IDENTIFY PROJECTS, THE AREAS AFFECTED, AND LIMITING FACTORS ADDRESSED

An initial array of alternatives has been formulated based on initial data collection and best professional judgment including input from Mason County, the Skokomish Tribe, and local, state, and Federal agencies. The study team identified over 25 management measures (features or activities that can be implemented at a specific geographic site) as possibly implementable in the study area. Management measures include large-scale sediment removal, construction of setback levees, placement of large woody debris, side channel restoration, and riparian plantings. Each measure was qualitatively assessed and a determination was made as to whether it should move forward in the formulation of alternative plans.

After preliminary screening, 19 management measures were carried forward to the next plan formulation step: identification of potential restoration sites. The study team identified approximately 60 potential sites where one or more measures could be implemented to address the unique problems of the study area. Sites were selected based on locations of severe degradation within the study area; the team used best professional judgment to determine what measure(s) would function at each site for intended benefits.

To guide alternatives formulation, the study team identified the study’s highest priorities. If these priorities are not met, the study will fail to address the most severe biological needs of the system. The study has six priorities:

1. Increase channel capacity
2. Address river reach that runs dry during summer months
3. Reduce sediment accumulation
4. Reconnect side channels and tributaries
5. Restore floodplain riparian buffer zone
6. Improve habitat complexity and functionality

The initial array of alternatives was formulated based on initial data collection and best professional judgment. The study team identified which of the approximately 60 potential restoration sites address the highest study priorities. This exercise led to the development of alternatives that include a “base” measure. The "bases" are key measures at specific sites or reaches of the river that address the highest priorities of the study area (increasing channel capacity, improving sediment transport, and addressing summer low flow; ultimately keeping fish in the river to spawn, rear, and migrate). The bases are large projects with no separable elements; they are also mutually exclusive from other bases. Developing alternatives around these base measures ensures the critical needs of the study area are addressed. An alternative cannot be considered complete, acceptable, or effective unless one of these bases is included. The base alternatives include two large-scale sediment removal options that reach across multiple river reaches plus two smaller-scale restoration projects within specific reaches of the river.

Increments will be added to the focused array of four base alternatives to capture supplementary benefits associated with restoration of additional channel and floodplain habitat features. Potential increments considered for addition to the base plans were selected from the list of 19 proposed management measures and 60 potential restoration sites using best professional judgment. These increments are generally smaller and can be added to whichever base option becomes the preferred alternative. The first increment added to base plans includes placement of LWD. This measure was identified to be the first critical habitat feature that should be included in a recommended plan in addition to the base; LWD helps establish pools, trap excessive sediment, improves stream habitat complexity, and serves as a substrate for aquatic invertebrates that salmon rely on as a food source. Next, additional in-channel increments were considered to address the highest study priorities (increasing channel capacity, improving sediment transport, addressing summer low flow connectivity). Finally, additional floodplain increments were considered as lower priority restoration features. Potential floodplain increments include removal of blockages at the mouths of tributaries, restoration of side channel habitat, creation of new side channels, and levee setbacks.

Of the approximately 60 potential restoration sites, eight sites were identified by the study team as high priority in-channel or floodplain increments that would optimize the environmental benefits for an alternative plan. A cost-effectiveness/incremental cost analysis (CE/ICA) will determine the appropriate number and scale of cost effective increments. The combinability of projects to base plans is further described in Chapter 4 along with the overall CE/ICA framework for the study.

Table 12 includes key information about the base alternatives in blue and the additional channel and floodplain increments in green including project name, description, reach or reaches affected, limiting factor addressed, and affected acreage (acres calculated using GIS). Figure 22 shows a map of the study area with all of the projects being carried forward in the environmental benefits analysis at this point in the plan formulation process. Finally, Figures 23 through 26 show conceptual drawings of the four proposed base plans: Bases 1, 2, 3, and 5, respectively.

Table 12. Potential restoration projects including notes regarding their design. The assessment metrics (limiting factors addressed), affected areas and reaches are identified. Where a single project spans more than one reach, the affected acreage is allocated accordingly.

NEW ID	RM	PLAN NAME	SITE PROBLEM OR NEED	PLAN DESCRIPTION	ASSESSMENT AREA LIMITING FACTOR(S)	GIS ACRES	AFFECTED REACH(ES)
"BASE" ALTERNATIVES							
59	0-9	BASE #1 Complete Channel Capacity Dredging with LWD	Aggradation reduces fish access and migration. Limited LWD in river system.	Dredge from RM 0 to RM 9 (complete mainstem dredge). Place several pieces of LWD or ELJs in the main channel to provide additional fish habitat.	Channel capacity and in-channel habitat	219	0-4
50	9	BASE #2 Confluence Channel Excavation with LWD	Subsurface flow; limited connectivity to upper reaches due to aggradation. Limited LWD in river system.	Dredging and installation of ELJ or a fish weir near the confluence. Place several pieces of LWD or ELJs in the main channel near the original confluence or near RM 1 of the North Fork. LWD placement would provide additional fish habitat.	Channel capacity and in-channel habitat	26	4
31	9	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal with LWD	Car body levees act as an unnatural buffer and limits habitat connectivity to side channels and riparian zones. Limited LWD in river system.	Remove car body levee & reconnect channel on North Fork (allow flows to naturally divert to North Fork). Place several pieces of LWD or ELJs in the North Fork Channel near the original confluence (vicinity of RM 1 of the North Fork).	Channel capacity and in-channel habitat	68	4
62	3.5-9	BASE #5 RM 3.5-9 Dredge with LWD	Aggradation reduces fish access and migration. Limited LWD in river system.	Dredge from RM 3.5 to RM 9. Place several pieces of LWD or ELJs in the main channel to provide additional fish habitat.	Channel capacity and in-channel habitat	132	2-4

NEW ID	RM	PLAN NAME	SITE PROBLEM OR NEED	PLAN DESCRIPTION	ASSESSMENT AREA LIMITING FACTOR(S)	GIS ACRES	AFFECTED REACH(ES)
ADDITIONAL INCREMENTS TO BASE ALTERNATIVES							
9	4	River Channel	Rearing and migration opportunities are significantly limited in a remnant river channel with a poor connection to the mainstem.	Improve the hydraulic connection of an existing abandoned channel to make it more accessible for fish habitat. This improvement would occur at both the upstream and downstream ends of the channel. The channel would provide slower velocity habitat and higher flow connection; will not carry river flows year round. Because there is existing riparian vegetation in the channel, limited LWD placement or plantings would occur if necessary and be focused near the agricultural field in the area. The channel would rejoin the old oxbow at the downstream end of the site.	Floodplain habitat	45	2 / 3
26	10	Dips Rd	West Valley Road acts as a physical barrier to riparian habitat connectivity.	Relocate a small area of West Valley Road near the Dips to the West Valley Wall. Remove road surface, scarify roadbed, breach embankments at select locations where the roadbed is higher than the ground elevation, and remove riprap to create a higher-functioning riparian habitat and reconnected riparian zone.	Floodplain habitat	17	4
28	9	Large Levee Setback	The connection to riparian habitats is restricted by a levee near the mainstem bank.	Setback levee to provide access to additional riparian habitats including an overwintering pool. Assume existing levee breach will remain open (do not repair this area).	Floodplain habitat	23	4
35	11	Upstream LWD Installation	Spawning, rearing, and refuge habitats (including pools) are limited in RM 9 to 11 due to a lack of LWD in the upstream reaches of the Skokomish River.	Place LWD structures to create pools and provide cover.	In-channel habitat	107	4 / 5
37	8	Grange Dike Setback	The connection to riparian habitats is restricted by the Grange Dike near the mainstem bank.	Set levee back to provide access to additional riparian habitat including a pool.	Floodplain habitat	34	4 / 3
39	6	Hunter Creek - Mouth	There is a poor connection between the mouth of Hunter Creek and the mainstem.	Small-scale excavation at the mouth of Hunter Creek to provide year-round access between the Creek and mainstem river.	Floodplain habitat	0.5	3

NEW ID	RM	PLAN NAME	SITE PROBLEM OR NEED	PLAN DESCRIPTION	ASSESSMENT AREA LIMITING FACTOR(S)	GIS ACRES	AFFECTED REACH(ES)
40	6	Hunter Creek Side Channel Restoration	Fish stranding commonly occurs at this site due to limited side channels off Hunter Creek; spawning and rearing opportunities are significantly limited in Hunter Creek.	Excavate remnant channels (identified by LIDAR) to provide improved side channel habitat including refuge for juvenile fish during high flows. Riparian buffer plantings would also occur at this site.	Floodplain habitat	29	3
43	6	Weaver Creek Side Channel Restoration	A lack of juvenile salmonid rearing habitat & stranded fish during high flow events.	Limited excavation of remnant channels (identified by LIDAR) to provide improved side channel habitat including refuge for juvenile fish during high flows. Riparian buffer plantings would also occur at this site.	In-channel habitat	25	3

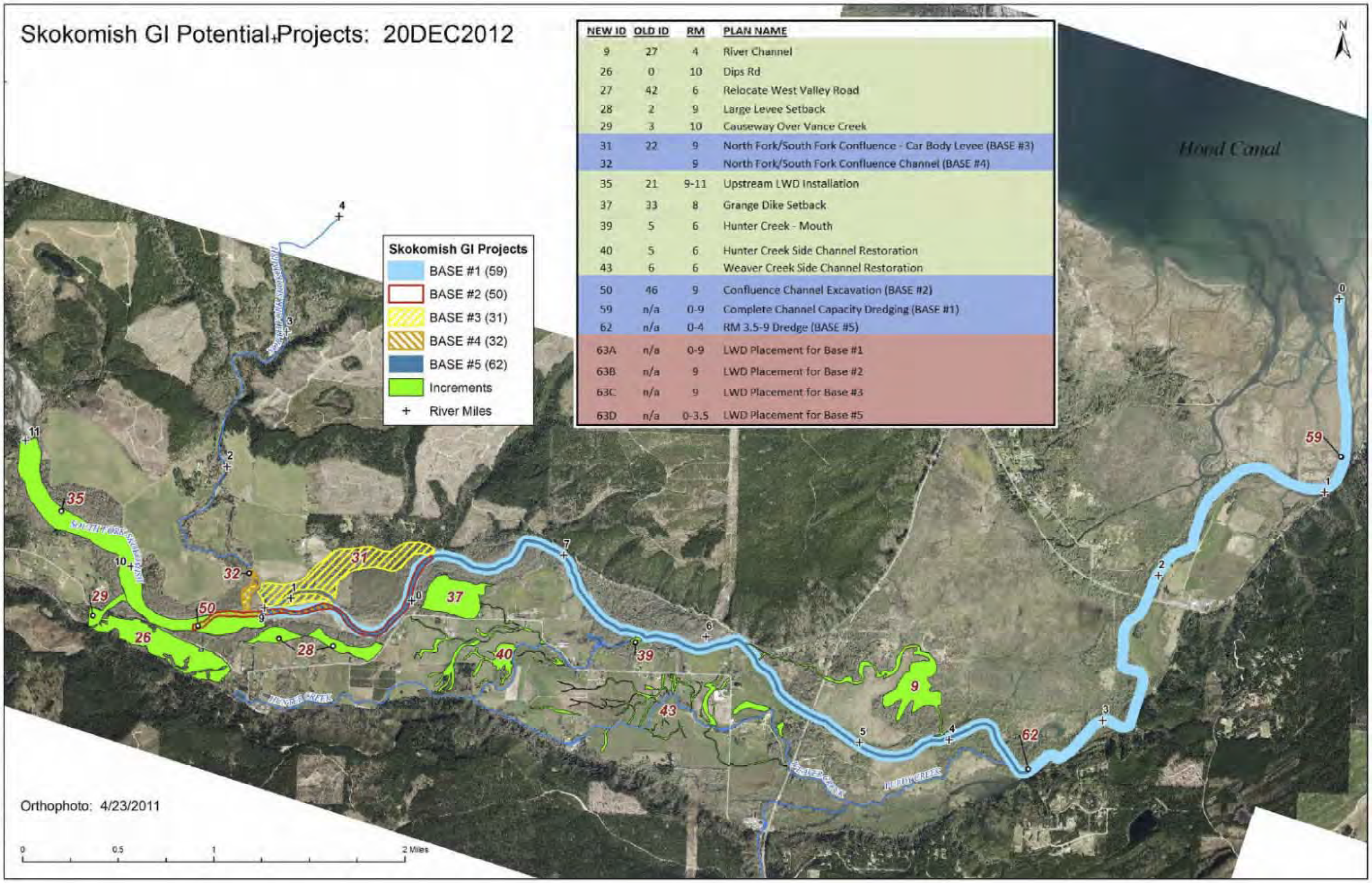

Figure 22. Skokomish GI screened base plans and incremental projects

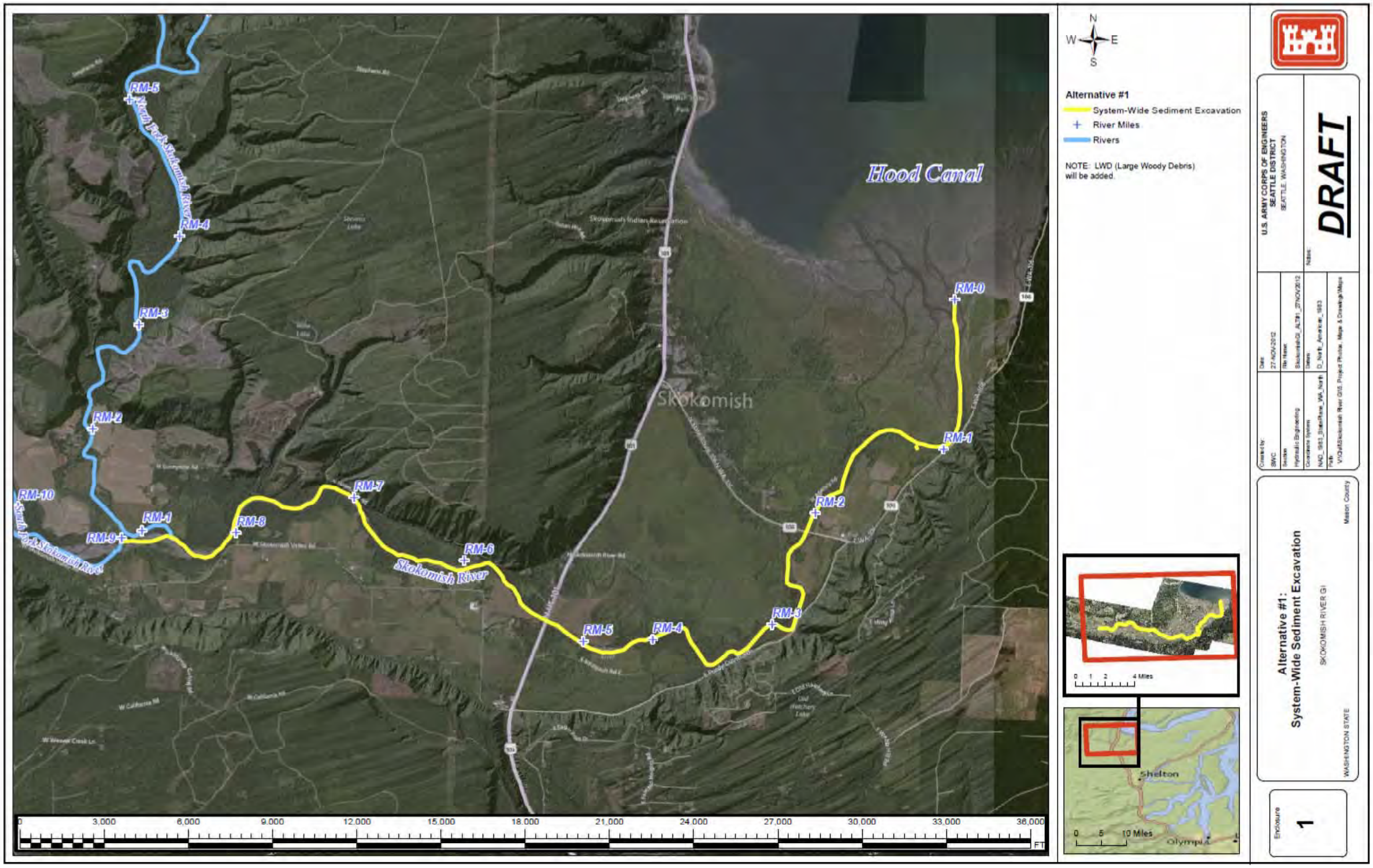

Figure 23. Base Alternative #1 - System-Wide Sediment Excavation from River Mile 0 to 9 and LWD

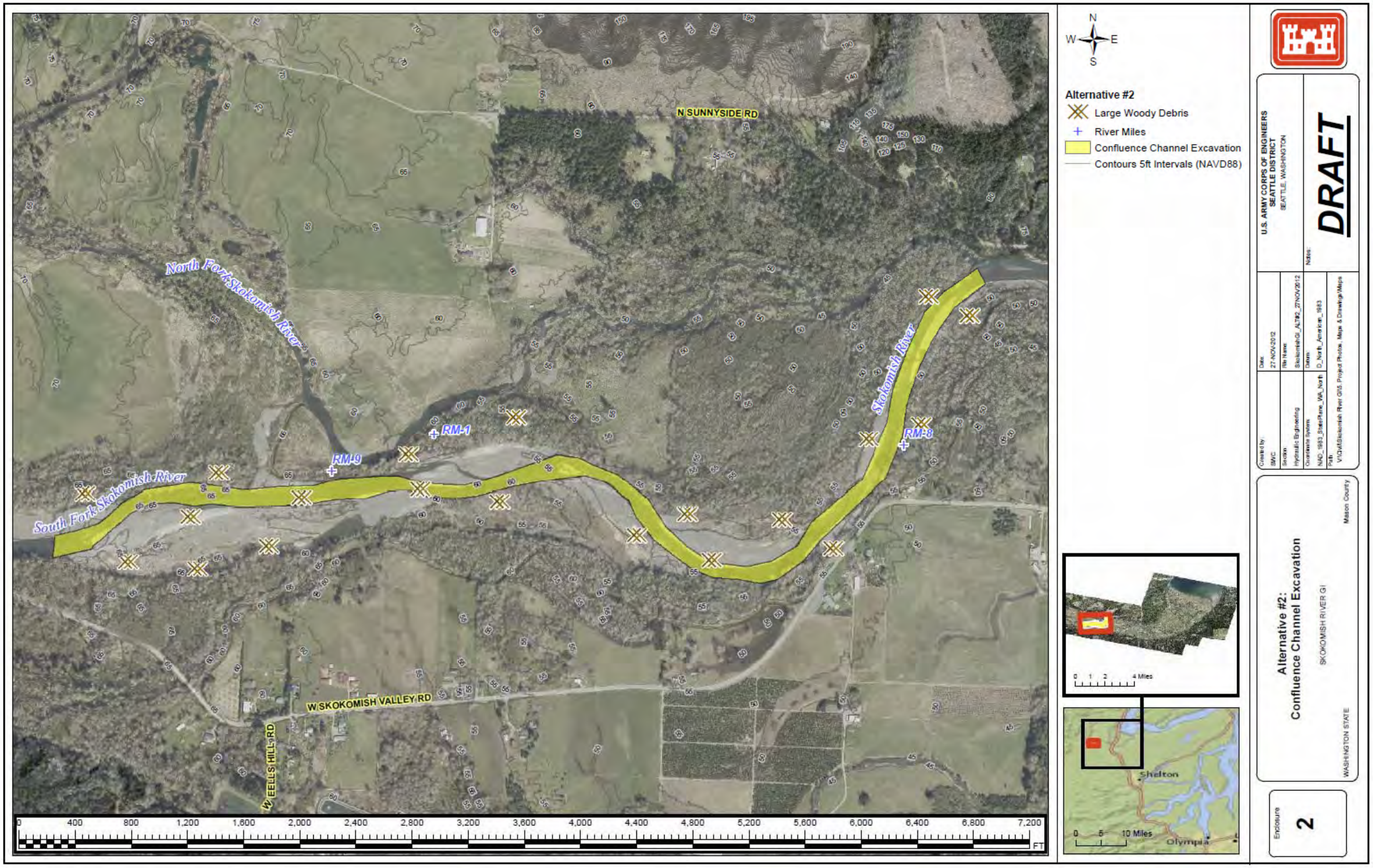

Figure 24. Base Alternative #2 - North Fork Confluence Channel Excavation and LWD

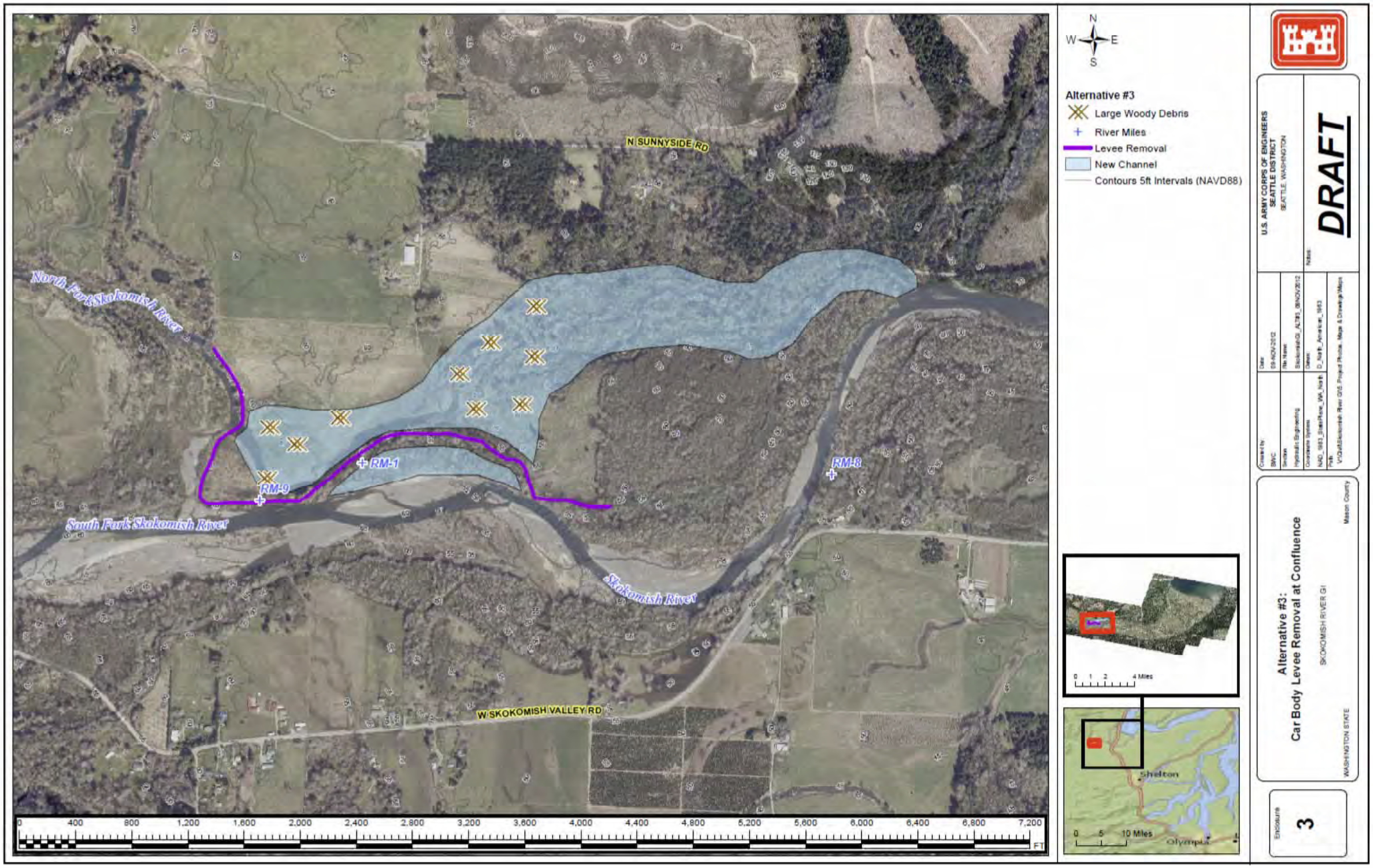

Figure 25. Base Alternative #3 - North Fork Confluence Car Body Levee Removal and LWD

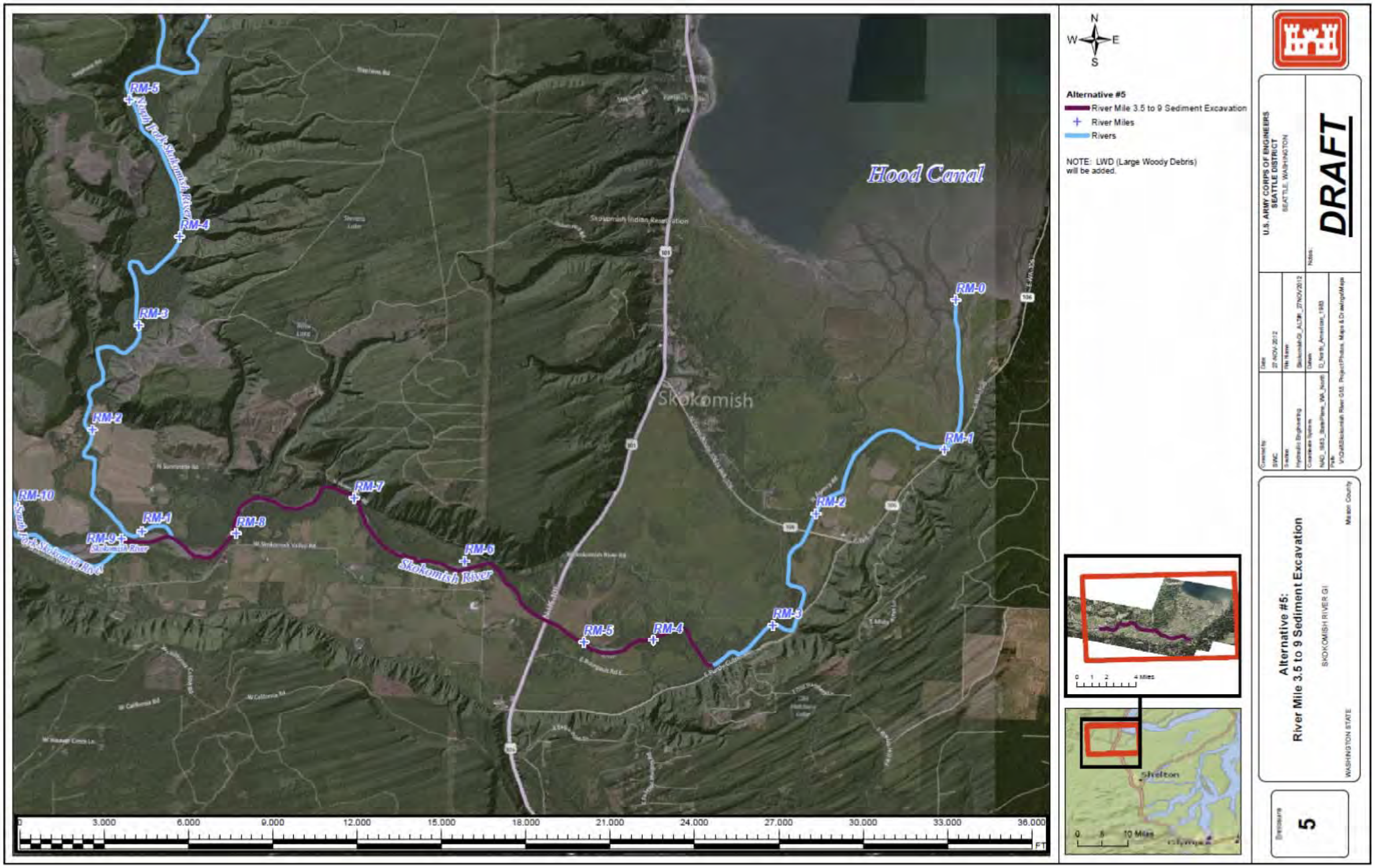

Figure 26. Base Alternative #5 - Sediment Excavation from River Mile 3.5 to 9 and LWD

4 EVALUATE SPECIFIC PROPOSED COMBINATIONS OF PROJECTS

An exercise was done to determine which projects are combinable and which are mutually exclusive. No two base plans are combinable and are therefore mutually exclusive. The capacity dredging with large woody debris base alternatives (Projects 59, 50, 31, and 62) are the first increments for any one alternative plan. In IWR Planning Suite, there will be a rule that each incremental project is dependent on one of the base alternatives and no two base alternatives are combinable.

AAHUs are computed for an assessment area by multiplying the HQI given the applicable limiting factor(s) and the affected acres as follows:

$$AAHU = HQI\ x\ Affected\ Area$$

Table 13 summarizes the combinability of increments to base plans, denoted with a ‘Y’ for combinable and ‘N’ for not combinable. This table is included in the Environmental Benefits Analysis spreadsheet model in the worksheet titled ‘CombinabilityBasePlans’ and informed the project increments in Table 14. The increments are included in the worksheet ‘IncrementstoBases’ in the Environmental Benefits Analysis spreadsheet model. Habitat benefits for each of these project increments are evaluated in the worksheet ‘CE ICA INPUT DATA’.

For each proposed restoration action, it was first determined whether the project assessment area for that action would result in measureable change to the channel capacity, in-channel habitat, or floodplain habitat limiting factors. After determining applicable limiting factor(s) for a project assessment area, the without project and with project habitat quality index scores for relevant assessment metrics were estimated. For example, a project that would address in-channel habitat only would be evaluated using the in-channel habitat assessment metrics for LWD and percent surface area in pools.

Many of the proposed projects have multiple types of benefits and may include LWD and pool formation even though they are considered a floodplain connection project. The rationale for not scoring a project on all four assessment metrics that represent the floodplain and in-channel limiting factors is that most of the projects will not include all four components or contribute to enhancing all of the habitat features represented by all four assessment metrics. In general, the side channel projects are scored as benefiting connectivity, and the levee setback projects are score as contributing to riparian habitat. The LWD installation is scored under the in-channel habitat limiting factor; as an in-channel measure, it will not contribute to floodplain connectivity. Additionally, the effort applied to calculating the relative area of effect of more than two different components does not provide a commensurate level of precision in scoring, nor is this level of precision necessary to compare the projects.

The channel capacity limiting factor with its assessment metric of flow capacity is reserved for application to the base options. The rationale for this is that the incremental projects do not accomplish flow capacity because of their small size compared to the volume of floodwater or because of their location being different from where the problematic flooding occurs.

Table 13. Combinability of Incremental Projects with Base Alternatives

Project Number	Project Name	Base #1	Base #2	Base #3	Base #5
59	BASE #1 Complete Channel Capacity Dredging (RM 0-9) with LWD	Y	N	N	N
50	BASE #2 Confluence Channel Excavation with LWD	N	Y	N	N
31	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal with LWD	N	N	Y	N
62	BASE #5 RM 3.5-9 Dredge with LWD	N	N	N	Y
9	River Channel	Y	Y	Y	Y
26	Dips Road	Y	Y	Y	Y
28	Large Levee Setback	Y	Y	Y	Y
35	Upstream LWD Installation	Y	Y	Y	Y
37	Grange Dike	Y	Y	Y	Y
39	Hunter Creek Mouth	N	Y	Y	N
40	Hunter Creek Side Channel Habitat Reconnection	Y	Y	Y	Y
43	Weaver Creek Side Channel	Y	Y	Y	Y

Table 14. Project Increments Assigned to Base Alternatives Based on Combinability

Project Number	Base # Assignment	Project Number/ Base	Project Name	Affected Reach(es)	Affected Acres	Limiting Factor
59	1	K1	BASE #1 Complete Channel Capacity Dredging (RM 0-9) with LWD	0-4	219	Channel Capacity and In-Channel Habitat
50	2	L1	BASE #2 Confluence Channel Excavation with LWD	4	26	Channel Capacity and In-Channel Habitat
31	3	M1	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal with LWD	4	68	Channel Capacity and In-Channel Habitat
62	5	N1	BASE #5 RM 3.5-9 Dredge with LWD	2-4	132	Channel Capacity and In-Channel Habitat
9	all	B1	River Channel	2-3	45	Floodplain Habitat
26	all	C1	Dips Road	4	17	Floodplain Habitat
28	all	D1	Large Levee Setback	4	23	Floodplain Habitat
35	all	F1	Upstream LWD Installation	4-5	107	In-Channel Habitat
37	all	G1	Grange Dike	3-4	34	Floodplain Habitat
39	2 and 3	H1	Hunter Creek Mouth	3	0.5	Floodplain Habitat
40	all	I1	Hunter Creek Side Channel Habitat Reconnection	3	29	Floodplain Habitat
43	all	J1	Weaver Creek Side Channel	3	25	In-Channel Habitat

The following flow diagram in Figure 27 shows the assessment metrics (labeled V1 to V5), limiting factors and three paths to compute habitat quality index depending on which of the limiting factors apply for a given assessment area.

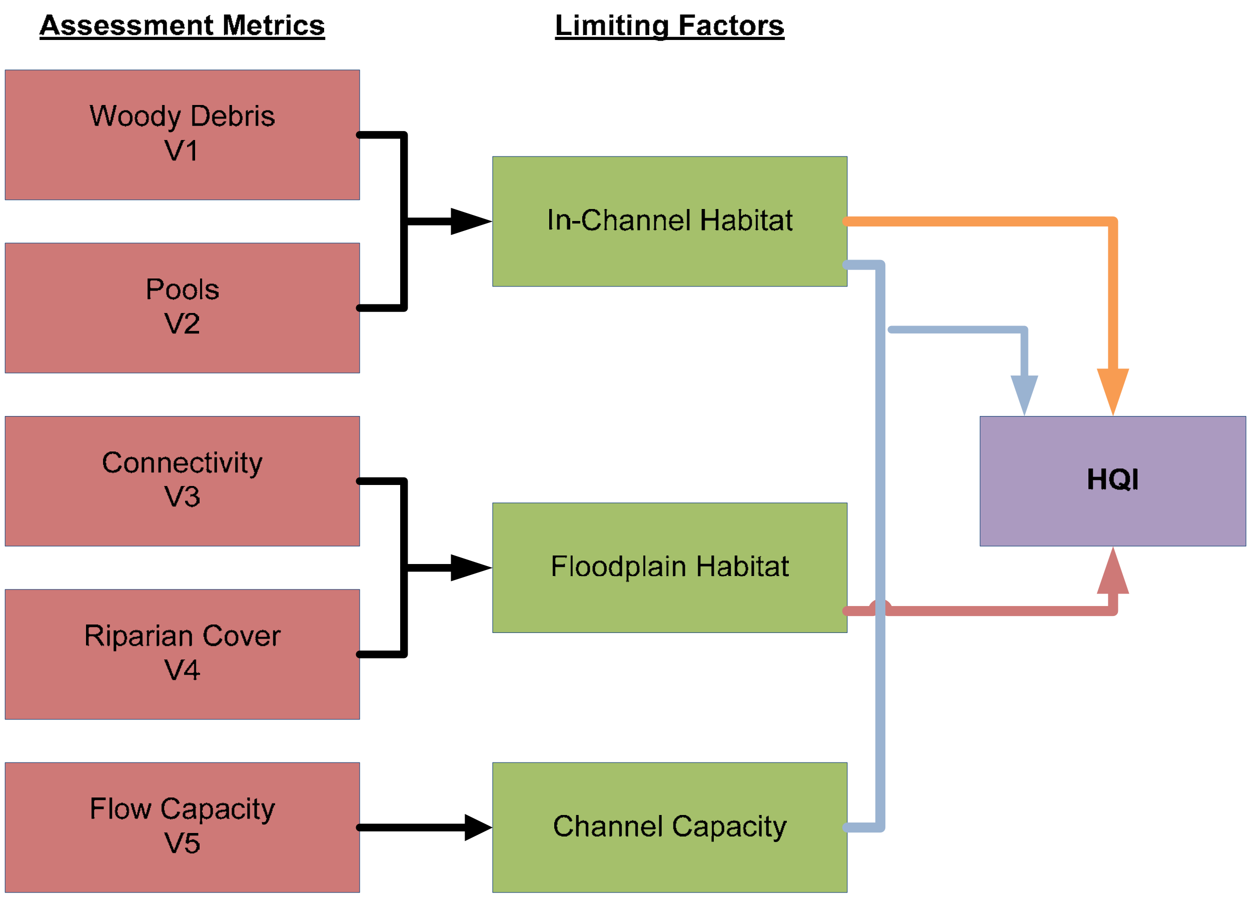

Figure 27. Flow diagram of HQI computation based on assessment area limiting factor(s) and assessment metrics

HQI is equal to one of three equations depending on the limiting factor(s) that apply to a given assessment area:

- $HQI = \frac{V1+V2+V5}{3}$ for assessment areas which evaluate both channel capacity and in-channel habitat limiting factors;
- $HQI = \frac{V1+V2}{2}$ for assessment areas which evaluate the in-channel habitat limiting factor only; and
- $HQI = \frac{V3+V4}{2}$ for assessment areas that evaluate the floodplain habitat limiting factor only.

AAHUs are computed for an assessment area by multiplying the HQI given the applicable limiting factor(s) and the affected acres as follows:

$$AAHU = HQI \; x \; Affected \; Area$$

Tables 15 to 17 show the evaluation of assessment areas by limiting factor(s) proposed project increments address. Table 15 includes computation of AAHUs for project increments that evaluate channel capacity and in-channel habitat limiting factors; Table 16 evaluates project increments for the floodplain habitat limiting factor only, and Table 17 evaluates project increments for the in-channel habitat limiting factor only. For each assessment area, three evaluations are presented. The first line is the evaluation of the without project condition for the assessment areas and is denoted by a letter followed by 0. It is scored based on the applicable limiting factor(s) and HQI is computed using the applicable HQI equation. The second line is for the project increment (with-project action) and is denoted with the same project letter followed by 1. It evaluates the habitat quality associated with the proposed action and is scored using the same assessment metrics used in the without project condition. Lastly, the third line presents the benefits of the proposed action. The benefits are taken as the change in HQI score multiplied by the affected area of the project.

$$Benefits\ (in\ AAHU) = Change\ in\ HQI\ Score\ (With\ Project - Without\ Project)\ x\ Affected\ Area$$

Table 15. HQI scoring and AAHU's for assessment areas with channel capacity and in-channel habitat limiting factors

						QI Scores for Applicable Variables						
Project Number	**Base # Assignment**	**Project Number/Base**	**Affected Reach(es)**	**Primary Reach Affected**	**Affected Acres**	**V1 - Woody Debris**	**V2 - Pools**	**V3 - Connectivity**	**V4 - Riparian Cover**	**V5 - Capacity**	**HQI**	**AAHU (Affected Acres * HQI)**
Limiting Factors for Assessment Area = Channel Capacity and In-Channel Habitat HQI = (V1 + V2 + V5)/3												
59	1	K0	0-4	N/A	219	0.10	0.21	N/A	N/A	0.03	0.11	24.5
59	1	K1	0-4	N/A	219	0.93	0.93	N/A	N/A	1.00	0.95	208.7
59	***1***	***K1***	***0-4***	***N/A***	***219***	***0.83***	***0.72***	***N/A***	***N/A***	***0.97***	***0.84***	***184.2***
50	2	L0	4	N/A	26	0.10	0.21	N/A	N/A	0.03	0.11	*2.9*
50	2	L1	4	N/A	26	0.93	0.93	N/A	N/A	0.50	0.79	20.4
50	***2***	***L1***	***4***	***N/A***	***26***	***0.83***	***0.72***	***N/A***	***N/A***	***0.47***	***0.67***	***17.5***
31	3	M0	4	N/A	68	0.10	0.21	N/A	N/A	0.03	0.11	*7.6*
31	3	M1	4	N/A	68	0.93	0.93	N/A	N/A	0.50	0.79	*53.5*
31	***3***	***M1***	***4***	***N/A***	***68***	***0.83***	***0.72***	***N/A***	***N/A***	***0.47***	***0.67***	***45.9***
62	5	N0	2-4	N/A	132	0.10	0.21	N/A	N/A	0.03	0.11	*14.8*
62	5	N1	2-4	N/A	132	0.93	0.93	N/A	N/A	1.00	0.95	*125.8*
62	***5***	***N1***	***2-4***	***N/A***	***132***	***0.83***	***0.72***	***N/A***	***N/A***	***0.97***	***0.84***	***111.0***

Table 16. HQI scoring and AAHU's for assessment areas with floodplain habitat limiting factors

						QI Scores for Applicable Variables						
Project Number	**Base # Assignment**	**Project Number/Base**	**Affected Reach(es)**	**Primary Reach Affected**	**Affected Acres**	**V1 - Woody Debris**	**V2 - Pools**	**V3 - Connectivity**	**V4 - Riparian Cover**	**V5 - Capacity**	**HQI**	**AAHU (Affected Acres * HQI)**
Limiting Factors for Assessment Area = Floodplain Habitat HQI = (V3 + V4) / 2												
9	all	B0	2-3	3	45	N/A	N/A	-	0.68	N/A	0.34	15.3
9	all	B1	2-3	3	45	N/A	N/A	0.94	0.88	N/A	0.91	41.0
9	***all***	***B1***	***2-3***	***3***	***45***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.57***	***25.7***
26	all	C0	4	4	17	N/A	N/A	-	0.40	N/A	0.20	3.4
26	all	C1	4	4	17	N/A	N/A	0.94	0.95	N/A	0.95	16.1
26	***all***	***C1***	***4***	***4***	***17***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.75***	***12.7***
28	all	D0	4	4	23	N/A	N/A	-	0.55	N/A	0.28	6.3
28	all	D1	4	4	23	N/A	N/A	0.94	0.79	N/A	0.87	19.9
28	***all***	***D1***	***4***	***4***	***23***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.59***	***13.6***
37	all	G0	3-4	4	34	N/A	N/A	-	0.61	N/A	0.31	10.4
37	all	G1	3-4	4	34	N/A	N/A	0.94	0.76	N/A	0.85	28.9
37	***all***	***G1***	***3-4***	***4***	***34***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.54***	***18.5***
39	2 and 3	H0	3	3	0.5	N/A	N/A	-	0.81	N/A	0.41	0.2
39	2 and 3	H1	3	3	0.5	N/A	N/A	0.94	0.88	N/A	0.91	0.5
39	***2 and 3***	***H1***	***3***	***3***	***0.5***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.51***	***0.3***
40	all	I0	3	3	29	N/A	N/A	-	0.10	N/A	0.05	1.5
40	all	I1	3	3	29	N/A	N/A	0.94	0.54	N/A	0.74	21.5
40	***all***	***I1***	***3***	***3***	***29***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.69***	***20.1***

Table 17. HQI scoring and AAHU's for assessment areas with in-channel habitat limiting factors

						QI Scores for Applicable Variables						
Project Number	**Base # Assignment**	**Project Number/Base**	**Affected Reach(es)**	**Primary Reach Affected**	**Affected Acres**	**V1 - Woody Debris**	**V2 - Pools**	**V3 - Connectivity**	**V4 - Riparian Cover**	**V5 - Capacity**	**HQI**	**AAHU (Affected Acres * HQI)**
Limiting Factors for Assessment Area = In-Channel Habitat HQI = (V1 + V2) / 2												
9	all	B0	2-3	3	45	N/A	N/A	-	0.68	N/A	0.34	16.6
9	all	B1	2-3	3	45	N/A	N/A	0.94	0.88	N/A	0.91	99.5
9	***all***	***B1***	***2-3***	***3***	***45***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.57***	***82.9***
26	all	C0	4	4	17	N/A	N/A	-	0.40	N/A	0.20	3.9
26	all	C1	4	4	17	N/A	N/A	0.94	0.95	N/A	0.95	23.2
26	***all***	***C1***	***4***	***4***	***17***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.75***	***19.4***

5 SUMMARIZED CE/ICA INPUT DATA FOR IWR-PLANNING SUITE

For the purposes of comparing and evaluating alternatives, the AAHUs will be used in IWR-Planning Suite to evaluate the cost effectiveness and incremental cost of the base alternatives in combinations with the additional incremental projects. Total AAHU for incremental projects are equal to the difference in AAHU's for the without-project condition and the with-project condition for a given assessment area. Table 18 summarizes the benefits for each project increment to be used for the cost effectiveness and incremental cost analysis (CE/ICA) in IWR-Planning Suite.

Table 18. Summary of project increment benefits for CE/ICA in IWR-Planning Suite

Project Number	Base # Assignment	Project Number/Base	Project Name	Limiting Factor	Affected Reach(es)	Affected Acres	HQI	AAHU (Affected Acres * HQI)
59	1	K1	BASE #1 Complete Channel Capacity Dredging (RM 0-9) with LWD	Channel Capacity and In-Channel Habitat	0-4	219	0.84	184.2
50	2	L1	BASE #2 Confluence Channel Excavation with LWD	Channel Capacity and In-Channel Habitat	4	26	0.67	17.5
31	3	M1	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal with LWD	Channel Capacity and In-Channel Habitat	4	68	0.67	45.9
62	5	N1	BASE #5 RM 3.5-9 Dredge with LWD	Channel Capacity and In-Channel Habitat	2-4	132	0.84	111.0
9	all	B1	River Channel	Floodplain Habitat	2-3	45	0.57	25.7
26	all	C1	Dips Road	Floodplain Habitat	4	17	0.75	12.7
28	all	D1	Large Levee Setback	Floodplain Habitat	4	23	0.59	13.6
35	all	F1	Upstream LWD Installation	In-Channel Habitat	4-5	107	0.77	82.9
37	all	G1	Grange Dike	Floodplain Habitat	3-4	34	0.54	18.5
39	2 and 3	H1	Hunter Creek Mouth	Floodplain Habitat	3	0.5	0.51	0.3
40	all	I1	Hunter Creek Side Channel Habitat Reconnection	Floodplain Habitat	3	29	0.69	20.1
43	all	J1	Weaver Creek Side Channel	In-Channel Habitat	3	25	0.77	19.4

6 HOW CE/ICA INPUT DATA WILL BE USED IN IWR PLAN FOR CE/ICA ANALYSIS

It is intended that the AAHU will be used in IWR Planning Suite, certified version 2.0.6.0. Conceptual level costs are being developed for each of the incremental projects and their annualized costs will be used in the model for the cost component. Alternatives will be evaluated using the annualized construction first costs and annual operations and maintenance (O&M) costs, and the total average annual cost, which considers life cycle costs of the project.

It is anticipated that the base plans will have a large cost range and the suite of alternatives generated will show large jumps in incremental cost from one base to another. Total project cost and habitat improvement will be considered in the identification of alternatives to carry forward analysis under the National Environmental Policy Act. It may be worthwhile to carry forward a single alternative plan for each of the base alternatives that reasonably meet both sponsor cost share capability and priority habitat needs in the basin.

7 SENSITIVITY ANALYSIS

A sensitivity analysis of the habitat outputs (AAHUs) was performed to consider different weighting of the assessment metrics for the three HQI equations. Lack of channel capacity is a priority problem in the Skokomish study area and is only addressed to some extent with the base alternatives. Both the channel capacity and in-channel habitat limiting factors apply to the computation of HQI scores for the four base alternatives using the following equation:

$$HQI = \frac{V1 + V2 + V5}{3}$$

If we were to prioritize the channel capacity and weight flow capacity (V5) higher than the other two in-channel habitat assessment metrics (woody debris or V1, and pools or V2) such that flow capacity is twice as important as both V1 and V2, the HQI equation for channel capacity and in-channel habitat limiting factors would be modified as follows:

$$HQI = \frac{V1 + V2 + (2 \times V5)}{4}$$

Table 19 presents the change in HQI scores that result from weighting flow capacity twice as important as woody debris and pools for the four base alternatives. Overall change in the benefit evaluations result in a change of -7.4% to +4.0% for each affected acre. Because the scale, costs, and benefits for each of the base alternatives are greatly different, the minor changes in overall habitat quality associated with weighting capacity higher than the other two metrics would have no affect on the cost effectiveness and incremental cost analysis for these base alternatives.

Table 19. Sensitivity analysis: Weighting flow capacity (V5) twice as great as woody debris (V1) and pools (V2) for HQI computations of channel capacity and in-channel habitat limiting factors

Scenario	HQI	Scenario	HQI	Scenario	HQI	Scenario	HQI
Base 1, equal weighting of metrics	0.84	Base 2, equal weighting of metrics	0.67	Base 3, equal weighting of metrics	0.67	Base 5, equal weighting of metrics	0.84
Base 1, capacity weighted 2x	0.87	Base 2, capacity weighted 2x	0.62	Base 3, capacity weighted 2x	0.62	Base 5, capacity weighted 2x	0.87
Change in Base 1 HQI	+0.03	Change in Base 2 HQI	-0.05	Change in Base 3 HQI	-0.05	Change in Base 5 HQI	+0.03
% Change in AAHU	+4.0%	% Change in AAHU	-7.4%	% Change in AAHU	-7.4%	% Change in AAHU	+4.0%

For assessment areas that only evaluate one of the limiting factors, in-channel habitat or floodplain habitat, a sensitivity analysis on the HQI score was performed to consider weighting of one the assessment metrics to be two times more important than the other assessment metric. The equations used for the computation of in-channel habitat (woody debris or V1, and pools or V2) and floodplain habitat (connectivity or V3, and riparian habitat or V4) considered equal weighting of each of the metrics with the following equations:

- $HQI = \frac{V1+V2}{2}$ for in-channel habitat, and
- $HQI = \frac{V3+V4}{2}$ for floodplain habitat.

Weighing one assessment metric twice as great as the other assessment metric modifies these two equations as follows:

- $HQI = \frac{(2\times V1)+V2}{3}$ for in-channel habitat where V1 is twice as great as V2;
- $HQI = \frac{V1+(2\times V2)}{3}$ for in-channel habitat where V2 is twice as great as V1;
- $HQI = \frac{(2\times V3)+V4}{3}$ for floodplain habitat where V3 is twice as great as V4; and
- $HQI = \frac{V3+(2\times V4)}{3}$ for floodplain habitat where V4 is twice as great as V3.

Table 20 presents the HQI computations for project increments that address either in-channel habitat or floodplain habitat limiting factors for each of the weightings and compare the changes to HQI computations where assessment metrics are equally weighted. Overall change in the benefit evaluations result in a change of -28.5% to +28.5% for each affected acre. The project increments for these assessment areas are of much smaller scale than the base alternatives and would not affect the cost effectiveness and incremental cost analysis of the bases, but may result in minor changes to the overall cost effectiveness of the additional project increments in combination with the base alternatives.

Table 20. Sensitivity analysis: Weighting one assessment metric twice as great as other assessment metric for HQI computations of in-channel or floodplain habitat limiting factors

Project ID	V1 = V2	V1 = 2 x V2	V2 = 2 x V1	Project ID	V3 = V4	V3 = 2 x V4	V4 = 2 x V3
F1	0.77	0.79	0.76	B1	0.57	0.70	0.45
J1	0.77	0.79	0.76	C1	0.75	0.81	0.68
				D1	0.59	0.71	0.47
				G1	0.54	0.68	0.41
				H1	0.51	0.65	0.36
				I1	0.69	0.77	0.61

Because the overall sensitivity to the weighting of metrics is likely to have minor effects on the cost effectiveness and incremental cost analysis, and because there is no basis found in literature to weight the measures, the team will perform the analysis assuming equal weighting of the metrics for each of the three HQI equations.

8 MODEL UNCERTAINTIES AND LIMITATIONS

With any attempt to quantify ecosystem benefits of restoration, the method will have inherent uncertainties and limitations. We have identified several in the process of developing this ecosystem benefits model. They are summarized as follows:

1) Amount of benefits not quantified

    a. We use the Salmonidae family as a “keystone species,” and as the most important ESA-listed species, for calculating habitat benefits. This assumes the majority of benefits are quantified through the metrics focused on salmonid habitat needs. The model has only five different assessment metrics, so this leaves entire categories of salmon habitat benefits unquantified.

    b. We assume that other benefits will accrue for avian, mammal, insect, and bivalve species; however, the model does not include direct predictive measurements, so there is some unknown quantity of benefits for these other biota. This is identified as one of the limitations of this model in that it is not a comprehensive accounting of all classes of biota that are expected to experience benefits.

    c. The biggest limitation of this model is that combining the unrelated qualities represented by the capacity metric versus the in-channel and floodplain metrics, then taking the average of these metrics, reduces the value of providing the critical population survival component afforded by the channel capacity measure. The results severely underestimate the value of the two alternatives that provide increased channel capacity that would reduce annual fish mortality from stranding outside the channel.

2) Benefits beyond the project footprint

    a. Successful restoration is expected to enhance salmon habitat and thereby help to increase their populations, which occupy and traverse through areas well outside of the project footprint. Salmon are a prey item for many other species, and influence structure and function throughout their spawning range, as well as provide marine derived nutrients back to the land-based, freshwater ecosystem. This model uses project footprint as the area component, which is smaller than the total area of influence of the anticipated increase in biological benefits as salmon move upstream and downstream from the project areas.

    b. Another limitation of this model is that it does not calculate the potential change in process and structure upstream and downstream from the project footprint that may accrue due to placement of LWD or removal of significant quantities of sediment. Risk and uncertainty of these actions are analyzed in the Draft Feasibility Report/Environmental Impact Statement and other project documents to ensure human safety and minimized environmental impacts; however, the benefits calculation is limited to the project footprint due to uncertainty of scope of benefits outside of the immediate project area.

3) Project design and implementation results

    a. We assume that significant sediment removal from the aggraded river to the two-year flood flow capacity will have significant short-term impacts, such as turbidity during construction, but will significantly reduce the overbank flooding that causes adult and juvenile salmonids to become stranded in the agricultural fields. The model bases benefits on the concept that this will increase the survival rate of the egg-to-migrant fry life stage. Since there have been no before-after-control-impact studies to quantify this increase in survival rate, we have a large degree of uncertainty regarding the quantification of this expected improvement in the Skokomish River.

    b. Design guidance was provided from the project fish biologist to the design engineers regarding appropriate and target quantities of LWD placement. We assume that adding LWD to the river to achieve the target based on best available science in the most recent literature on LWD loading in Pacific Northwest streams will achieve the desired effects (see: Fox et al. 2003, Fox and Bolton 2007). LWD that is anchored during construction is expected to recruit and trap other woody debris that travels downstream from the forested upper watershed. One of the limitations of this model is that there is no quantification of benefits from the growing mass of LWD recruited post construction due to uncertainty of rate and quantities.

    c. The most likely scenario for operations and maintenance of the project is to implement a recurring dredging program. This is assumed the most efficient and least environmentally damaging, compared to other options such as a sediment trap, because a regular dredging program would only remove what deposits. A sediment trap would induce deposition and require dredging every year. A trap may fill during a large flood and then bypass sediment for the rest of the year. A sediment trap is a continuous operation (trapping or removing) and may be an obstruction to fish passage. Compared to a sediment trap, periodic dredging would occur much less frequently, only when needed. For Base Options 1 and 5, a multi-year dredging plan could be implemented, rotating the dredging location. Current estimates are that dredging every 20 years could maintain capacity between the 1.33 to two-year flood return intervals for the larger dredging alternatives. For the Base Option that dredges at the North Fork confluence, dredging every 10 years would be required to maintain capacity because the confluence area is shallower than other reaches of the river.

4) Predictability of inputs from the upper watershed above the study area

    a. Water: We have large uncertainty regarding the flood flows that will occur during and after construction. We can only calculate the probability of any flow level based on history of exceedances, but cannot predict what will occur during and after construction.

b. LWD: The upper watershed of the Skokomish basin has large logjams and is largely forested across most of the landscape. LWD inputs into the study area are difficult to predict, but may be improving as landscape management of commercial forestry practices improves.

c. Sediment: The Corps estimates that the bedload inflow from the upper watershed is approximately 30,000 to 40,000 cubic yards per year. The primary source is natural erosion with some contribution from landslides that may occur due to present or past timber harvests on steep slopes or logging roads that cause erosion and sedimentation. The contributions from forestry practices are assumed to be decreasing as roads are being decommissioned on public lands and more erosion prevention measures are used in public and private timber harvests. However, the primary source is a natural occurrence and the rate cannot be precisely predicted for any given year, only in averages and trends.

5) Operational modifications at Cushman Dam on the North Fork Skokomish River

a. Seattle District is familiar with the provisions of the relicensing agreement and will continue to coordinate with the settlement parties as alternative plans are developed. The settlement agreement places no legal restrictions or responsibilities on the Corps.

b. The settlement agreement has established monthly base flows that are being implemented by the operating project; flushing flows are not being implemented at this time due to a lack of channel capacity to carry the flows (flushing flows would induce flooding downstream of the dam).

c. Operation of upstream reservoirs has been taken into consideration during the alternatives formulation process; the without project condition and future without project includes the current and likely future flow regimes from Cushman Dam. Future flow modifications from Cushman Dam could increase flows in the North Fork (e.g., implementation of North Fork flushing flows), though the impacts of these flows would minimally affect the alternatives proposed under the GI. The recommended plan may allow for the future implementation of flushing flows but the Corps will not formulate, evaluate, or select a plan based on this effect. Dam flows from the North Fork enter the study area at RM 7.5, while the study area extends upstream to RM 12.

6) Habitat development after construction

a. Each metric has assumptions stated for the temporal scale of how benefits will accrue after construction. These are based on literature, best professional judgment, and Corps staff’s personal observations of similar projects.

b. Primary uncertainty lies within the prediction of stability of the riverbed after significant quantities of sediment are removed. There is no metric to score for more or less stability.

c. Quantity and velocity of water will affect development of habitat after construction, so this ties back to the inability to predict when and what level of high flow events will occur after construction.

7) Predicting future with-project and future without-project

   a. Uncertainties regarding predicting the future have largely been covered previously in this chapter. One of the limitations specific to the scores for future without project is that using the relationship derived from historical data to predict the future assumes that there are certain steady-state conditions among the complex ecosystem processes, structures, and functions. We assume that the degrading habitat will continue to degrade at the same rate, or that it is already as bad as it can get and therefore the score for the future without-project is the same as the existing conditions.

   b. Predicting the future with-project scores relies on the assumption that the project will function as designed and therefore deserves the score it is given according to the metric. There is unquantifiable uncertainty in this outcome, but a Monitoring and Adaptive Management Plan will be designed to maximize benefits.

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Appendix A: Skokomish Environmental Benefits Analysis Spreadsheet – A Guide to the Worksheets and Computations

The intent of this appendix is to support the documentation of the main model documentation report and provide a guide to the worksheets contained within the Skokomish Environmental Benefits Analysis Spreadsheet. Tables and information contained within the worksheet are provided here, along with the formulas used to derive environmental outputs for project increments considered for the Skokomish River General Investigation at this time. Each Section corresponds to a single worksheet within the model, which also corresponds to the ID's in Section 1, Table of Contents.

Background to the assessment metrics, valuations, and equations are contained in the main report. The functions used within the model are directly related to the information provided in the main report. Much of the information contained within the spreadsheet was derived from team input and no computations were required. The table found in the 'CE ICA INPUT DATA' worksheet contains the majority of the computations that will feed the cost effectiveness and incremental cost analyses (CE/ICA) for the study.

1 TABLE OF CONTENTS

A table of contents worksheet is included to provide links to the individual worksheets within the model. A total of 12 worksheets are included and are summarized as follows.

ID	Worksheet	Content Description
1	Table of Contents	This tab describes the contents of each of the worksheets included in the Skokomish Environmental Benefits Analysis (EBA) Spreadsheet Model. The EBA Model is used to derive the environmental outputs needed to evaluate alternatives in IWR-Planning Suite for cost effectiveness and incremental analysis. The procedures, environmental basis for the outputs, and the plan formulation are described in the model certification document that accompanies this report.
2	INPUT DATA	These are the project increments/measures identified by the project development team (PDT) to address degraded habitat in the lower Skokomish River Basin. Included are the project number, project name, affected reach or reaches, a primary affected reach, affected acreage, and a designation of which limiting factors apply to the assessment area. This project data is carried forward in the development of average annual habitat units and is included in several other worksheets including 'CombinabilityBasePlans', 'IncrementstoBases', and 'CE ICA INPUT DATA'.

ID	Worksheet	Content Description
3	CombinabilityBasePlans	The PDT conducted an exercise to identify combinability of projects and measures to the bases. No two incremental projects are mutually exclusive, and all other project increments are combinable with exception of the four base alternatives.
4	IncrementstoBases	This worksheet carries forward the project information from the 'INPUT DATA' worksheet and the project relationships from the 'CombinabilityBasePlans' worksheet to show all of the possible incremental projects and the bases they may be combined with. Projects are denoted by a letter and number for CE/ICA in IWR-Planning Suite.
5	Assessment Metric HQI	The assessment metric existing, future without-project, and future with-project condition, and average annual HQI benefit scores (or change from the without project condition to the with project condition) are summarized here. The existing, future without-project, and future with-project scores are derived in worksheets for each of the assessment metrics ('Channel – Pools HQI', 'Channel - Woody Debris HQI', 'Floodplain - Riparian Cover HQI', and 'Floodplain – Connectivity HQI'). These HQI scores are used for computation of average annual habitat units in the 'CE/ICA INPUT DATA' worksheet.
6	Capacity HQI	This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the flow capacity assessment metric over the study period for each of the base alternatives.
7	Channel – Pools HQI	This worksheet documents the computations of the existing future without-project, and future with-project HQI scores by assessing change in habitat quality for the pool assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without-project and future with-project conditions.
8	Channel - Woody Debris HQI	This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the woody debris assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without-project and future with-project conditions.

ID	Worksheet	Content Description
9	Floodplain - Riparian Cover HQI	This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the riparian cover assessment metric over the study period for each of the assessment areas. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without-project and future with-project conditions.
10	Floodplain – Connectivity HQI	This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the connectivity assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without-project and future with-project conditions.
11	CE ICA INPUT DATA	This worksheet contains the computations of AAHU by assessment area and net benefits for each of the project increments. The benefits will be used for cost effectiveness and incremental cost analyses (CE/ICA) analysis in IWR-Planning Suite.
12	CE ICA Sensitivity Analysis	This worksheet presents a sensitivity analysis of the change in HQI and AAHU when one assessment metric is weighted greater than the other one or two assessment metrics for the three HQI equations.

2 ‘INPUT DATA’ WORKSHEET

These are the project increments/measures identified by the study team to address degraded habitat in the lower Skokomish River Basin. Items included are the project number, project name, affected reach or reaches, a primary affected reach, affected acreage, and applicable limiting factor(s) for the assessment area. This project data is carried forward in the development of average annual habitat units and is included in several other worksheets including 'CombinabilityBasePlans', 'IncrementstoBases', and 'CE ICA INPUT DATA'. This table is included as Table 14 in the main model documentation report.

3 ‘COMBINABILITYBASEPLANS’ WORKSHEET

The PDT went through an exercise to identify combinability of projects/measures to the bases. No two incremental projects are mutually exclusive, and thus all incremental projects combinable with a base were also combinable with one another. This table is included as Table 13 in the main model documentation report.

AAHUs are computed for an assessment area by multiplying the HQI given the applicable limiting factor(s) and the affected acres as follows:

$$AAHU = HQI \ x \ Affected\ Area$$

4 ‘INCREMENTSTOBASES’ WORKSHEET

This worksheet carries forward the project information from the 'INPUT DATA' worksheet and the project relationships from the 'CombinabilityBasePlans' worksheet to show all of the possible increments of projects and the bases to which they may be assigned. This was a planning exercise and no formulas are included in this worksheet. This table is included as Table 13 in the main model documentation report.

5 ‘ASSESSMENT METRIC HQI’ WORKSHEET

The assessment metric existing, future without-project and future with-project condition, and average annual HQI benefit (or change from the without project condition to the with project condition) are summarized here. The existing, future without-project, and future with-project scores are derived in worksheets for each of the assessment metrics (‘Capacity HQI’, 'Channel – Pools HQI', 'Channel - Woody Debris HQI', 'Floodplain - Riparian Cover HQI', and 'Floodplain – Connectivity HQI'). The formulas or locations for each of the values are provided to the right in the following table.

Row /Column	B	C	D	E	F	G	H	I	*F*	*G*	*H*	*I*
4	Limiting Factor	Assessment Metric	Base	Project ID	Existing Habitat Quality Index Score	Average Future Without-Project (FWOP) Habitat Quality Index Score	Average Future With-Project (FWP) Habitat Quality Index Score	Average Benefit (change in HQI from FWOP to FWP, or FWOP HQI - FWP HQI)	*Existing Habitat Quality Index Score*	*Average Future Without-Project (FWOP) Habitat Quality Index Score*	*Average Future With-Project (FWP) Habitat Quality Index Score*	*Average Benefit (change in HQI from FWOP to FWP, or FWOP HQI - FWP HQI)*
5												
6	Channel Habitat	Pools	all	N/A	0.21	0.21	0.93	0.72	*='Channel - Pools HQI'!B6*	*='Channel - Pools HQI'!B58*	*='Channel - Pools HQI'!C58*	*=H6-G6*
7		Woody Debris	all	N/A	0.10	0.10	0.93	0.83	*='Channel - Woody Debris HQI'!B6*	*='Channel - Woody Debris HQI'!B58*	*='Channel - Woody Debris HQI'!C58*	*=H7-G7*
8	Floodplain Habitat	Riparian Cover	all	9	0.68	0.68	0.88	0.20	*='Floodplain - Riparian Cover HQI'!B7*	*='Floodplain - Riparian Cover HQI'!B59*	*='Floodplain - Riparian Cover HQI'!C59*	*=H8-G8*
9			all	26	0.40	0.40	0.95	0.55	*='Floodplain - Riparian Cover HQI'!D7*	*='Floodplain - Riparian Cover HQI'!D59*	*='Floodplain - Riparian Cover HQI'!E59*	*=H9-G9*
10			all	28	0.55	0.55	0.79	0.24	*='Floodplain - Riparian Cover HQI'!F7*	*='Floodplain - Riparian Cover HQI'!F59*	*='Floodplain - Riparian Cover HQI'!G59*	*=H10-G10*
11			all	37	0.61	0.61	0.76	0.15	*='Floodplain - Riparian Cover HQI'!H7*	*='Floodplain - Riparian Cover HQI'!H59*	*='Floodplain - Riparian Cover HQI'!I59*	*=H11-G11*
12			all	39	0.81	0.81	0.88	0.07	*='Floodplain - Riparian Cover HQI'!J7*	*='Floodplain - Riparian Cover HQI'!J59*	*='Floodplain - Riparian Cover HQI'!K59*	*=H12-G12*

Row /Column	B	C	D	E	F	G	H	I	*F*	*G*	*H*	*I*
4	Limiting Factor	Assessment Metric	Base	Project ID	Existing Habitat Quality Index Score	Average Future Without-Project (FWOP) Habitat Quality Index Score	Average Future With-Project (FWP) Habitat Quality Index Score	Average Benefit (change in HQI from FWOP to FWP, or FWOP HQI - FWP HQI)	*Existing Habitat Quality Index Score*	*Average Future Without-Project (FWOP) Habitat Quality Index Score*	*Average Future With-Project (FWP) Habitat Quality Index Score*	*Average Benefit (change in HQI from FWOP to FWP, or FWOP HQI - FWP HQI)*
13			all	40	0.10	0.10	0.54	0.44	*='Floodplain - Riparian Cover HQI'!L7*	*='Floodplain - Riparian Cover HQI'!L59*	*='Floodplain - Riparian Cover HQI'!M59*	*=H13-G13*
14			all	43	0.06	0.06	0.45	0.39	*='Floodplain - Riparian Cover HQI'!N7*	*='Floodplain - Riparian Cover HQI'!N59*	*='Floodplain - Riparian Cover HQI'!O59*	*=H14-G14*
15		Connectivity	all	N/A	0.00	0.00	0.94	0.94	*='Floodplain - Connectivity HQI'!B6*	*='Floodplain - Connectivity HQI'!B58*	*='Floodplain - Connectivity HQI'!C58*	*=H15-G15*
16	Channel Capacity	Flow Capacity	1	N/A	0.17	0.17	1.00	0.83	*='Capacity HQI'!E6*	*='Capacity HQI'!F6*	*='Capacity HQI'!G6*	*=H16-G16*
17		Flow Capacity	2	N/A	0.17	0.17	0.50	0.33	*='Capacity HQI'!E7*	*='Capacity HQI'!F7*	*='Capacity HQI'!G7*	*=H17-G17*
18		Flow Capacity	3	N/A	0.17	0.17	0.50	0.33	*='Capacity HQI'!E8*	*='Capacity HQI'!F8*	*='Capacity HQI'!G8*	*=H18-G18*
19		Flow Capacity	5	N/A	0.17	0.17	1.00	0.83	*='Capacity HQI'!E9*	*='Capacity HQI'!F9*	*='Capacity HQI'!G9*	*=H19-G19*

6 'CAPACITY HQI' WORKSHEET

This worksheet documents the computations of the existing, future without- and future with-project HQI scores by assessing change in habitat quality for the flow capacity assessment metric over time. This is assessed by base alternative. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without and with project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annuals HQI scores for the future without- and future with-project conditions.

All base alternatives have an existing condition aggraded score of less than the one-year score, with flood recurrence at approximately four times per year in the existing condition and approaching no flood capacity by year 20 in the without project condition. With restoration, Bases 1 and 5 will provide approximately two-year flow capacity with a score equal to 1; Bases 2 and 3 will provide approximately one-year capacity with a score equal to 0.5. These values are displayed in the table below and are populated in the 'Assessment Metric HQI' worksheet.

Row / Column	B	C	D	E	F	G	H	*E*	*F*	*G*	*H*
4	Limiting Factor	Assessment Metric	Base	Existing Habitat Quality Index Score	Average Future Without-Project (FWOP) Habitat Quality Index Score	Average Future With-Project (FWP) Habitat Quality Index Score	Average Change in HQI from FWOP to FWP	*Existing Habitat Quality Index Score*	*Average Future Without-Project (FWOP) Habitat Quality Index Score*	*Average Future With-Project (FWP) Habitat Quality Index Score*	*Average Change in HQI from FWOP to FWP*
6	Channel Capacity	Flow Capacity	1	0.13	0.03	1.00	0.97	*=$B$40*	*=$B$92*	*=1/1*	*=G6-F6*
7	Channel Capacity	Flow Capacity	2	0.13	0.03	0.50	0.47	*=$B$40*	*=$B$92*	*=1/2*	*=G7-F7*
8	Channel Capacity	Flow Capacity	3	0.13	0.03	0.50	0.47	*=$B$40*	*=$B$92*	*=1/2*	*=G8-F8*
9	Channel Capacity	Flow Capacity	5	0.13	0.03	1.00	0.97	*=$B$40*	*=$B$92*	*=1/1*	*=G9-F9*

Row/Column	A	B	C	*B*	C
35	**WORKSHEET**				
36	**Quality index scores over the period of analysis**				
37	**Limiting Factor**	**Channel Capacity**			
38	**Assessment Metric**	**Flow Capacity**			
39	**Year**	**Without Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***
40	0	**0.13**		**=1/8**	
41	1	0.12	-0.6%	=B40+$C$41	=(B60-B40)/(A60-A40)
42	2	0.11		=B41+$C$41	

Row/Column	A	B	C	*B*	*C*
35	**WORKSHEET**				
36	**Quality index scores over the period of analysis**				
37	**Limiting Factor**	**Channel Capacity**			
38	**Assessment Metric**	**Flow Capacity**			
39	**Year**	**Without Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***
43	3	0.11		=B42+$C$41	
44	4	0.10		=B43+$C$41	
45	5	0.09		=B44+$C$41	
46	6	0.09		=B45+$C$41	
47	7	0.08		=B46+$C$41	
48	8	0.08		=B47+$C$41	
49	9	0.07		=B48+$C$41	
50	10	0.06		=B49+$C$41	
51	11	0.06		=B50+$C$41	
52	12	0.05		=B51+$C$41	
53	13	0.04		=B52+$C$41	
54	14	0.04		=B53+$C$41	
55	15	0.03		=B54+$C$41	
56	16	0.03		=B55+$C$41	
57	17	0.02		=B56+$C$41	
58	18	0.01		=B57+$C$41	
59	19	0.01		=B58+$C$41	
60	20	-		**0**	
61	21	-		0	
62	22	-		0	
63	23	-		0	
64	24	-		0	
65	25	-		0	
66	26	-		0	
67	27	-		0	
68	28	-		0	
69	29	-		0	
70	30	-		0	
71	31	-		0	
72	32	-		0	
73	33	-		0	
74	34	-		0	
75	35	-		0	
76	36	-		0	
77	37	-		0	
78	38	-		0	
79	39	-		0	
80	40	-		0	
81	41	-		0	
82	42	-		0	
83	43	-		0	
84	44	-		0	
85	45	-		0	
86	46	-		0	
87	47	-		0	
88	48	-		0	
89	49	-		0	
90	50	-		0	
91		**Without project condition**		**Without project condition**	
92	Average	0.03		=AVERAGE(B40:B90)	

7 'CHANNEL – POOLS HQI' WORKSHEET

This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the pool assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without- and with-project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annual HQI scores for the future without- and future with-project conditions. A graph is generated that plots the HQI values for the future without- and future with-project time curves over the period of analysis. Column D has equations to compute the slope (rise) between two known points. Formulas for each of the cells are contained in the columns to the right. More information about the habitat quality scoring and time curves for the future without- and with project HQI scores can be found within in the main report.

Row/ Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Channel Habitat**					
4	**Assessment Metric**	**Pools**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
6	0	**0.21**	**0.21**		**0.21**	**0.21**	
7	1	0.21	0.32		0.21	=C6+$D$9	
8	2	0.21	0.44		0.21	=C7+$D$9	
9	3	0.21	0.55	11.40%	0.21	=C8+$D$9	=(C11-C6)/(5-0)
10	4	0.21	0.67		0.21	=C9+$D$9	
11	5	0.21	**0.78**		0.21	**0.78**	
12	6	0.21	0.82	4.40%	0.21	=C11+$D$12	=(C16-C11)/(A16-A11)
13	7	0.21	0.87		0.21	=C12+$D$12	
14	8	0.21	0.91		0.21	=C13+$D$12	
15	9	0.21	0.96		0.21	=C14+$D$12	
16	10	0.21	**1.00**		0.21	**1**	
17	11	0.21	1.00		0.21	1	
18	12	0.21	1.00		0.21	1	
19	13	0.21	1.00		0.21	1	
20	14	0.21	1.00		0.21	1	
21	15	0.21	1.00		0.21	1	
22	16	0.21	1.00		0.21	1	
23	17	0.21	1.00		0.21	1	
24	18	0.21	1.00		0.21	1	
25	19	0.21	1.00		0.21	1	
26	20	0.21	1.00		0.21	1	
27	21	0.21	1.00		0.21	1	
28	22	0.21	1.00		0.21	1	
29	23	0.21	1.00		0.21	1	
30	24	0.21	1.00		0.21	1	
31	25	0.21	1.00		0.21	1	
32	26	0.21	1.00		0.21	1	
33	27	0.21	1.00		0.21	1	
34	28	0.21	1.00		0.21	1	

Row/Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Channel Habitat**					
4	**Assessment Metric**	**Pools**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
35	29	0.21	1.00		0.21	1	
36	30	0.21	1.00		0.21	1	
37	31	0.21	1.00		0.21	1	
38	32	0.21	1.00		0.21	1	
39	33	0.21	1.00		0.21	1	
40	34	0.21	1.00		0.21	1	
41	35	0.21	1.00		0.21	1	
42	36	0.21	1.00		0.21	1	
43	37	0.21	1.00		0.21	1	
44	38	0.21	1.00		0.21	1	
45	39	0.21	1.00		0.21	1	
46	40	0.21	1.00		0.21	1	
47	41	0.21	1.00		0.21	1	
48	42	0.21	1.00		0.21	1	
49	43	0.21	1.00		0.21	1	
50	44	0.21	1.00		0.21	1	
51	45	0.21	1.00		0.21	1	
52	46	0.21	1.00		0.21	1	
53	47	0.21	1.00		0.21	1	
54	48	0.21	1.00		0.21	1	
55	49	0.21	1.00		0.21	1	
56	50	0.21	1.00		0.21	1	
57		**Without project condition**	**With Project Condition**		**Without project condition**	**With Project Condition**	**Without project condition**
58	Average	0.21	0.93		=AVERAGE(B6:B56)	=AVERAGE(C6:C56)	=AVERAGE(B6:B56)
59	Average change (benefit)		0.72			=C58-B58	

8 'CHANNEL – WOODY DEBRIS HQI' WORKSHEET

This worksheet documents the computations of the existing, future without-project, and future with-project HQI scores by assessing change in habitat quality for the woody debris assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without- and with-project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annual HQI scores for the future without- and future with-project conditions. A graph is generated that plots the HQI values for the future without- and future with-project time curves over the period of analysis. Column D has equations to compute the slope (rise) between two known points. Formulas for each of the cells are contained in the columns to the right. More information about the habitat quality scoring and time curves for the future without- and with-project HQI scores can be found within in the main report.

Row/Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Channel Habitat**					
4	**Assessment Metric**	**Woody Debris**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
6	0	**0.10**	**0.10**		**0.1**	**0.1**	
7	1	0.10	0.24	14%	0.1	=C6+$D$7	=(C11-C6)/(A11-A6)
8	2	0.10	0.38		0.1	=C7+$D$7	
9	3	0.10	0.52		0.1	=C8+$D$7	
10	4	0.10	0.66		0.1	=C9+$D$7	
11	5	0.10	**0.80**		0.1	**0.8**	
12	6	0.10	0.84	4%	0.1	=C11+$D$12	=(C16-C11)/(A16-A11)
13	7	0.10	0.88		0.1	=C12+$D$12	
14	8	0.10	0.92		0.1	=C13+$D$12	
15	9	0.10	0.96		0.1	=C14+$D$12	
16	10	0.10	**1.00**		0.1	**1**	
17	11	0.10	1.00		0.1	=IF(C16+$D$7>1,1,C16+$D$7)	
18	12	0.10	1.00		0.1	=IF(C17+$D$7>1,1,C17+$D$7)	
19	13	0.10	1.00		0.1	=IF(C18+$D$7>1,1,C18+$D$7)	
20	14	0.10	1.00		0.1	=IF(C19+$D$7>1,1,C19+$D$7)	
21	15	0.10	1.00		0.1	=IF(C20+$D$7>1,1,C20+$D$7)	
22	16	0.10	1.00		0.1	=IF(C21+$D$7>1,1,C21+$D$7)	
23	17	0.10	1.00		0.1	=IF(C22+$D$7>1,1,C22+$D$7)	
24	18	0.10	1.00		0.1	=IF(C23+$D$7>1,1,C23+$D$7)	
25	19	0.10	1.00		0.1	=IF(C24+$D$7>1,1,C24+$D$7)	
26	20	0.10	1.00		0.1	=IF(C25+$D$7>1,1,C25+$D$7)	
27	21	0.10	1.00		0.1	=IF(C26+$D$7>1,1,C26+$D$7)	
28	22	0.10	1.00		0.1	=IF(C27+$D$7>1,1,C27+$D$7)	
29	23	0.10	1.00		0.1	=IF(C28+$D$7>1,1,C28+$D$7)	
30	24	0.10	1.00		0.1	=IF(C29+$D$7>1,1,C29+$D$7)	
31	25	0.10	1.00		0.1	=IF(C30+$D$7>1,1,C30+$D$7)	
32	26	0.10	1.00		0.1	=IF(C31+$D$7>1,1,C31+$D$7)	
33	27	0.10	1.00		0.1	=IF(C32+$D$7>1,1,C32+$D$7)	
34	28	0.10	1.00		0.1	=IF(C33+$D$7>1,1,C33+$D$7)	
35	29	0.10	1.00		0.1	=IF(C34+$D$7>1,1,C34+$D$7)	
36	30	0.10	1.00		0.1	=IF(C35+$D$7>1,1,C35+$D$7)	
37	31	0.10	1.00		0.1	=IF(C36+$D$7>1,1,C36+$D$7)	
38	32	0.10	1.00		0.1	=IF(C37+$D$7>1,1,C37+$D$7)	
39	33	0.10	1.00		0.1	=IF(C38+$D$7>1,1,C38+$D$7)	
40	34	0.10	1.00		0.1	=IF(C39+$D$7>1,1,C39+$D$7)	
41	35	0.10	1.00		0.1	=IF(C40+$D$7>1,1,C40+$D$7)	
42	36	0.10	1.00		0.1	=IF(C41+$D$7>1,1,C41+$D$7)	
43	37	0.10	1.00		0.1	=IF(C42+$D$7>1,1,C42+$D$7)	
44	38	0.10	1.00		0.1	=IF(C43+$D$7>1,1,C43+$D$7)	
45	39	0.10	1.00		0.1	=IF(C44+$D$7>1,1,C44+$D$7)	
46	40	0.10	1.00		0.1	=IF(C45+$D$7>1,1,C45+$D$7)	
47	41	0.10	1.00		0.1	=IF(C46+$D$7>1,1,C46+$D$7)	
48	42	0.10	1.00		0.1	=IF(C47+$D$7>1,1,C47+$D$7)	
49	43	0.10	1.00		0.1	=IF(C48+$D$7>1,1,C48+$D$7)	
50	44	0.10	1.00		0.1	=IF(C49+$D$7>1,1,C49+$D$7)	
51	45	0.10	1.00		0.1	=IF(C50+$D$7>1,1,C50+$D$7)	
52	46	0.10	1.00		0.1	=IF(C51+$D$7>1,1,C51+$D$7)	
53	47	0.10	1.00		0.1	=IF(C52+$D$7>1,1,C52+$D$7)	
54	48	0.10	1.00		0.1	=IF(C53+$D$7>1,1,C53+$D$7)	

Row/Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Channel Habitat**					
4	**Assessment Metric**	**Woody Debris**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
55	49	0.10	1.00		0.1	=IF(C54+$D$7>1,1,C54+$D$7)	
56	50	**0.10**	1.00		**0.1**	=IF(C55+$D$7>1,1,C55+$D$7)	
57							
58	Average	0.10	0.93		=AVERAGE(B6:B56)	=AVERAGE(C6:C56)	
59	Average change (benefit)		0.83			=C58-B58	

9 ‘FLOODPLAIN – RIPARIAN COVER HQI’ WORKSHEET

This worksheet documents the computations of the existing, future without- and future with-project HQI scores by assessing change in habitat quality for the riparian cover assessment metric over time. Habitat quality is assessed by assessment area for each of the project increments. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without- and with-project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annual HQI scores for the future without- and future with-project conditions. A graph is generated that plots the HQI values for the future without- and future with-project time curves for each of the assessment areas over the period of analysis. Formulas for each of the cells are contained in the second table. More information about the habitat quality scoring and time curves for the future without- and with-project HQI scores can be found within in the main report.

Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**WORKSHEET**														
2	**Quality index scores over the period of analysis**														
3	**Limiting Factor**	**Floodplain Habitat**													
4	**Assessment Metric**	**Riparian Cover**													
5	**Project Assessment Area**	**9**	**9**	**26**	**26**	**29**	**29**	**37**	**37**	**39**	**39**	**40**	**40**	**43**	**43**
6	**Year**	**Project 9 Without Project**	**Project 9 With Project**	**Project 26 Without Project**	**Project 26 With Project**	**Project 29 Without Project**	**Project 29 With Project**	**Project 37 Without Project**	**Project 37 With Project**	**Project 39 Without Project**	**Project 39 With Project**	**Project 40 Without Project**	**Project 40 With Project**	**Project 43 Without Project**	**Project 43 With Project**
7	**0**	**0.68**	**0.68**	**0.4**	**0.4**	**0.55**	**0.55**	**0.61**	**0.61**	**0.81**	**0.81**	**0.1**	**0.1**	**0.06**	**0.06**
8	**1**	0.68	0.72	0.4	0.50	0.55	0.59	0.61	0.64	0.81	0.82	0.1	0.18	0.06	0.13
9	**2**	0.68	0.75	0.4	0.59	0.55	0.63	0.61	0.66	0.81	0.84	0.1	0.25	0.06	0.19
10	**3**	0.68	0.79	0.4	0.69	0.55	0.67	0.61	0.69	0.81	0.85	0.1	0.33	0.06	0.26
11	**4**	0.68	0.82	0.4	0.78	0.55	0.72	0.61	0.71	0.81	0.86	0.1	0.41	0.06	0.33
12	**5**	0.68	**0.86**	0.4	**0.88**	0.55	**0.76**	0.61	**0.74**	0.81	**0.87**	0.1	**0.48**	0.06	**0.40**
13	**6**	0.68	0.86	0.4	0.90	0.55	0.77	0.61	0.74	0.81	0.88	0.1	0.50	0.06	0.41
14	**7**	0.68	0.87	0.4	0.93	0.55	0.78	0.61	0.75	0.81	0.88	0.1	0.52	0.06	0.43
15	**8**	0.68	0.88	0.4	0.95	0.55	0.79	0.61	0.76	0.81	0.88	0.1	0.54	0.06	0.45
16	**9**	0.68	0.89	0.4	0.98	0.55	0.80	0.61	0.76	0.81	0.89	0.1	0.56	0.06	0.46
17	**10**	0.68	**0.90**	0.4	**1**	0.55	**0.81**	0.61	**0.77**	0.81	**0.89**	0.1	**0.58**	0.06	**0.48**
18	**11**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
19	**12**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
20	**13**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
21	**14**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
22	**15**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
23	**16**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
24	**17**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
25	**18**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
26	**19**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
27	**20**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
28	**21**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
29	**22**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
30	**23**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
31	**24**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
32	**25**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
33	**26**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
34	**27**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
35	**28**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
36	**29**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
37	**30**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
38	**31**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
39	**32**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
40	**33**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
41	**34**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
42	**35**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
43	**36**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
44	**37**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
45	**38**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
46	**39**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
47	**40**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
48	**41**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
49	**42**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
50	**43**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
51	**44**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
52	**45**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
53	**46**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48

Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**WORKSHEET**														
2	**Quality index scores over the period of analysis**														
3	**Limiting Factor**	**Floodplain Habitat**													
4	**Assessment Metric**	**Riparian Cover**													
5	**Project Assessment Area**	**9**	**9**	**26**	**26**	**29**	**29**	**37**	**37**	**39**	**39**	**40**	**40**	**43**	**43**
6	**Year**	**Project 9 Without Project**	**Project 9 With Project**	**Project 26 Without Project**	**Project 26 With Project**	**Project 29 Without Project**	**Project 29 With Project**	**Project 37 Without Project**	**Project 37 With Project**	**Project 39 Without Project**	**Project 39 With Project**	**Project 40 Without Project**	**Project 40 With Project**	**Project 43 Without Project**	**Project 43 With Project**
54	**47**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
55	**48**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
56	**49**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
57	**50**	0.68	0.90	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
58		**9 WOP**	**9 WP**	**26 WOP**	**26 WP**	**28 WOP**	**29 WP**	**37 WOP**	**37 WP**	**39 WOP**	**39 WP**	**40 WOP**	**40 WP**	**43 WOP**	**43 WP**
59	**Average**	0.68	0.88	0.40	0.95	0.55	0.79	0.61	0.76	0.81	0.88	0.10	0.54	0.06	0.45
60	**Average change (benefit)**		0.20		0.55		0.24		0.15		0.07		0.44		0.39

Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**WORKSHEET**														
2	**Quality index scores over the period of analysis**														
3	**Limiting Factor**	**Floodplain Habitat**													
4	**Assessment Metric**	**Riparian Cover**													
5	**Project Assessment Area**	**9**	**9**	**26**	**26**	**29**	**29**	**37**	**37**	**39**	**39**	**40**	**40**	**43**	**43**
6	**Year**	**Project 9 Without Project**	**Project 9 With Project**	**Project 26 Without Project**	**Project 26 With Project**	**Project 29 Without Project**	**Project 29 With Project**	**Project 37 Without Project**	**Project 37 With Project**	**Project 39 Without Project**	**Project 39 With Project**	**Project 40 Without Project**	**Project 40 With Project**	**Project 43 Without Project**	**Project 43 With Project**
7	**0**	**0.68**	**0.68**	**0.4**	**0.4**	**0.55**	**0.55**	**0.61**	**0.61**	**0.81**	**0.81**	**0.1**	**0.1**	**0.06**	**0.06**
8	**1**	0.68	=C7+((C$12-C$7)/($A$12-$A$7))	0.4	=E7+((E$12-E$7)/($A$12-$A$7))	0.55	=G7+((G$12-G$7)/($A$12-$A$7))	0.61	=I7+((I$12-I$7)/($A$12-$A$7))	0.81	=K7+((K$12-K$7)/($A$12-$A$7))	0.1	=M7+((M$12-M$7)/($A$12-$A$7))	0.06	=O7+((O$12-O$7)/($A$12-$A$7))
9	**2**	0.68	=C8+((C$12-C$7)/($A$12-$A$7))	0.4	=E8+((E$12-E$7)/($A$12-$A$7))	0.55	=G8+((G$12-G$7)/($A$12-$A$7))	0.61	=I8+((I$12-I$7)/($A$12-$A$7))	0.81	=K8+((K$12-K$7)/($A$12-$A$7))	0.1	=M8+((M$12-M$7)/($A$12-$A$7))	0.06	=O8+((O$12-O$7)/($A$12-$A$7))
10	**3**	0.68	=C9+((C$12-C$7)/($A$12-$A$7))	0.4	=E9+((E$12-E$7)/($A$12-$A$7))	0.55	=G9+((G$12-G$7)/($A$12-$A$7))	0.61	=I9+((I$12-I$7)/($A$12-$A$7))	0.81	=K9+((K$12-K$7)/($A$12-$A$7))	0.1	=M9+((M$12-M$7)/($A$12-$A$7))	0.06	=O9+((O$12-O$7)/($A$12-$A$7))
11	**4**	0.68	=C10+((C$12-C$7)/($A$12-$A$7))	0.4	=E10+((E$12-E$7)/($A$12-$A$7))	0.55	=G10+((G$12-G$7)/($A$12-$A$7))	0.61	=I10+((I$12-I$7)/($A$12-$A$7))	0.81	=K10+((K$12-K$7)/($A$12-$A$7))	0.1	=M10+((M$12-M$7)/($A$12-$A$7))	0.06	=O10+((O$12-O$7)/($A$12-$A$7))
12	**5**	0.68	**=0.8*(C17-C7)+C7**	0.4	**=0.8*(E17-E7)+E7**	0.55	**=0.8*(G17-G7)+G7**	0.61	**=0.8*(I17-I7)+I7**	0.81	**=0.8*(K17-K7)+K7**	0.1	**=0.8*(M17-M7)+M7**	0.06	**=0.8*(O17-O7)+O7**
13	**6**	0.68	=C12+((C$17-C$12)/($A$17-$A$12))	0.4	=E12+((E$17-E$12)/($A$17-$A$12))	0.55	=G12+((G$17-G$12)/($A$17-$A$12))	0.61	=I12+((I$17-I$12)/($A$17-$A$12))	0.81	=K12+((K$17-K$12)/($A$17-$A$12))	0.1	=M12+((M$17-M$12)/($A$17-$A$12))	0.06	=O12+((O$17-O$12)/($A$17-$A$12))
14	**7**	0.68	=C13+((C$17-C$12)/(A	0.4	=E13+((E$17-E$12)/(A	0.55	=G13+((G$17-G$12)/(A	0.61	=I13+((I$17-I$12)/(A	0.81	=K13+((K$17-K$12)/(A	0.1	=M13+((M$17-M$12)/($A	0.06	=O13+((O$17-O$12)/(A

Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**WORKSHEET**														
2	**Quality index scores over the period of analysis**														
3	**Limiting Factor**	**Floodplain Habitat**													
4	**Assessment Metric**	**Riparian Cover**													
5	**Project Assessment Area**	**9**	**9**	**26**	**26**	**29**	**29**	**37**	**37**	**39**	**39**	**40**	**40**	**43**	**43**
6	**Year**	**Project 9 Without Project**	**Project 9 With Project**	**Project 26 Without Project**	**Project 26 With Project**	**Project 29 Without Project**	**Project 29 With Project**	**Project 37 Without Project**	**Project 37 With Project**	**Project 39 Without Project**	**Project 39 With Project**	**Project 40 Without Project**	**Project 40 With Project**	**Project 43 Without Project**	**Project 43 With Project**
			17-$A$12))		17-$A$12))		17-$A$12))		17-$A$12))		17-$A$12))		$17-$A$12))		17-$A$12))
15	**8**	0.68	=C14+((C$17-C$12)/($A$17-$A$12))	0.4	=E14+((E$17-E$12)/($A$17-$A$12))	0.55	=G14+((G$17-G$12)/($A$17-$A$12))	0.61	=I14+((I$17-I$12)/($A$17-$A$12))	0.81	=K14+((K$17-K$12)/($A$17-$A$12))	0.1	=M14+((M$17-M$12)/($A$17-$A$12))	0.06	=O14+((O$17-O$12)/($A$17-$A$12))
16	**9**	0.68	=C15+((C$17-C$12)/($A$17-$A$12))	0.4	=E15+((E$17-E$12)/($A$17-$A$12))	0.55	=G15+((G$17-G$12)/($A$17-$A$12))	0.61	=I15+((I$17-I$12)/($A$17-$A$12))	0.81	=K15+((K$17-K$12)/($A$17-$A$12))	0.1	=M15+((M$17-M$12)/($A$17-$A$12))	0.06	=O15+((O$17-O$12)/($A$17-$A$12))
17	**10**	0.68	**0.9**	0.4	**1**	0.55	**0.81**	0.61	**0.77**	0.81	**0.89**	0.1	**0.58**	0.06	**0.48**
18	**11**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
19	**12**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
20	**13**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
21	**14**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
22	**15**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
23	**16**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
24	**17**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
25	**18**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
26	**19**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
27	**20**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
28	**21**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
29	**22**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
30	**23**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
31	**24**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
32	**25**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
33	**26**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
34	**27**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
35	**28**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
36	**29**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
37	**30**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
38	**31**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
39	**32**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
40	**33**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
41	**34**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
42	**35**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
43	**36**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
44	**37**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
45	**38**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
46	**39**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
47	**40**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
48	**41**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
49	**42**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
50	**43**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
51	**44**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
52	**45**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48

Row / Column	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**WORKSHEET**														
2	**Quality index scores over the period of analysis**														
3	**Limiting Factor**	**Floodplain Habitat**													
4	**Assessment Metric**	**Riparian Cover**													
5	**Project Assessment Area**	**9**	**9**	**26**	**26**	**29**	**29**	**37**	**37**	**39**	**39**	**40**	**40**	**43**	**43**
6	**Year**	**Project 9 Without Project**	**Project 9 With Project**	**Project 26 Without Project**	**Project 26 With Project**	**Project 29 Without Project**	**Project 29 With Project**	**Project 37 Without Project**	**Project 37 With Project**	**Project 39 Without Project**	**Project 39 With Project**	**Project 40 Without Project**	**Project 40 With Project**	**Project 43 Without Project**	**Project 43 With Project**
53	**46**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
54	**47**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
55	**48**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
56	**49**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
57	**50**	0.68	0.9	0.4	1	0.55	0.81	0.61	0.77	0.81	0.89	0.1	0.58	0.06	0.48
58		**9 WOP**	**9 WP**	**26 WOP**	**26 WP**	**28 WOP**	**29 WP**	**37 WOP**	**37 WP**	**39 WOP**	**39 WP**	**40 WOP**	**40 WP**	**43 WOP**	**43 WP**
59	**Average**	0.68	=AVERAGE(C7:C57)	=AVERAGE(D7:D57)	=AVERAGE(E7:E57)	=AVERAGE(F7:F57)	=AVERAGE(G7:G57)	=AVERAGE(H7:H57)	=AVERAGE(I7:I57)	=AVERAGE(J7:J57)	=AVERAGE(K7:K57)	=AVERAGE(L7:L57)	=AVERAGE(M7:M57)	=AVERAGE(N7:N57)	=AVERAGE(O7:O57)
60	**Average change (benefit)**		=C59-B59		=E59-D59		=G59-F59		=I59-H59		=K59-J59		=M59-L59		=O59-N59

10 'FLOODPLAIN – CONNECTIVITY HQI' WORKSHEET

This worksheet documents the computations of the existing, future without-project and future with-project HQI scores by assessing change in habitat quality for the connectivity assessment metric over time. Habitat changes were noted at appropriate points in time, and HQI scores were linearly interpolated between these points. The without- and with-project HQI scores average the HQI values over a 50-year time horizon. The benefit or change in habitat quality is the difference between the average annual HQI scores for the future without- and future with-project conditions. A graph is generated that plots the HQI values for the future without-project and future with-project time curves over the period of analysis. Column D has equations to compute the slope (rise) between two known points. Formulas for each of the cells are contained in the columns to the right. More information about the habitat quality scoring and time curves for the future without- and with-project HQI scores can be found within in the main report.

Row/Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Floodplain Habitat**					
4	**Assessment Metric**	**Connectivity**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
6	0	-	-		*0*	*0*	
7	1	-	0.20	0.20	*0*	*=C6+$D$7*	*=(C11-C6)/(A11-A6)*
8	2	-	0.40		*0*	*=C7+$D$7*	
9	3	-	0.60		*0*	*=C8+$D$7*	
10	4	-	0.80		*0*	*=C9+$D$7*	
11	5	-	**1.00**		*0*	*1*	
12	6	-	1.00		*0*	*1*	
13	7	-	1.00		*0*	*1*	
14	8	-	1.00		*0*	*1*	
15	9	-	1.00		*0*	*1*	
16	10	-	1.00		*0*	*1*	
17	11	-	1.00		*0*	*1*	
18	12	-	1.00		*0*	*1*	
19	13	-	1.00		*0*	*1*	
20	14	-	1.00		*0*	*1*	
21	15	-	1.00		*0*	*1*	
22	16	-	1.00		*0*	*1*	
23	17	-	1.00		*0*	*1*	
24	18	-	1.00		*0*	*1*	
25	19	-	1.00		*0*	*1*	
26	20	-	1.00		*0*	*1*	
27	21	-	1.00		*0*	*1*	
28	22	-	1.00		*0*	*1*	
29	23	-	1.00		*0*	*1*	
30	24	-	1.00		*0*	*1*	
31	25	-	1.00		*0*	*1*	
32	26	-	1.00		*0*	*1*	
33	27	-	1.00		*0*	*1*	
34	28	-	1.00		*0*	*1*	
35	29	-	1.00		*0*	*1*	
36	30	-	1.00		*0*	*1*	
37	31	-	1.00		*0*	*1*	

Row/Column	A	B	C	D	*B*	*C*	*D*
1	**WORKSHEET**						
2	**Quality index scores over the period of analysis**						
3	**Limiting Factor**	**Floodplain Habitat**					
4	**Assessment Metric**	**Connectivity**					
5	**Year**	**Without Project Condition**	**With Project Condition**	**Slope**	***Without Project Condition***	***With Project Condition***	***Slope***
38	32	-	1.00		*0*	*1*	
39	33	-	1.00		*0*	*1*	
40	34	-	1.00		*0*	*1*	
41	35	-	1.00		*0*	*1*	
42	36	-	1.00		*0*	*1*	
43	37	-	1.00		*0*	*1*	
44	38	-	1.00		*0*	*1*	
45	39	-	1.00		*0*	*1*	
46	40	-	1.00		*0*	*1*	
47	41	-	1.00		*0*	*1*	
48	42	-	1.00		*0*	*1*	
49	43	-	1.00		*0*	*1*	
50	44	-	1.00		*0*	*1*	
51	45	-	1.00		*0*	*1*	
52	46	-	1.00		*0*	*1*	
53	47	-	1.00		*0*	*1*	
54	48	-	1.00		*0*	*1*	
55	49	-	1.00		*0*	*1*	
56	50	-	1.00		*0*	*1*	
57							
58	Average	-	0.94		*=AVERAGE(B6:B56)*	*=AVERAGE(C6:C56)*	
59	Average change (benefit)		0.94			*=C58-B58*	

11 'CE ICA INPUT DATA' WORKSHEET

This worksheet summarizes scoring for without and with project conditions for each of the assessment areas, with computation of average annual habitat units (AAHUs) for the without project condition listed in the first row, computation of with project AAHUs in the second row, and the difference (or benefit, with – without project) displayed in the third row. The difference, or benefits, for each of the assessed projects will be used for cost effectiveness and incremental cost analysis (CE/ICA) in IWR-Planning Suite.

Projects are listed by applicable limiting factors. The first four projects, or base alternatives, address capacity and in-channel habitat and the average habitat quality index (HQI) score is computed by taking the average of V1 (woody debris), V2 (pools) and V5 (capacity), or (V1+V2+V5)/3. Six incremental projects address floodplain habitat and the average annual HQI score is computed by taking the average of V3 and V4, or (V3+V4)/2. Finally, two projects address in-channel habitat only and the average annual HQI score is computed by taking the average of V1 and V2, or (V1+V2)/2.

The first table shows the values for each of the assessed projects. The second table includes the formulas for scoring assessment metrics, computation of average annual HQI scores, and AAHUs.

Row/ Column	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
2									QI Scores for Applicable Variables						
3	Project Number	Base # Assignment	Project Number/Base	Project Name	Assessment Area Limiting Factor(s)	Affected Reach(es)	Primary Reach Affected	Affected Acres	V1 - Woody Debris	V2 - Pools	V3 - Connectivity	V4 - Riparian Cover	V5 - Capacity	HQI	AAHU (Affected Acres * HQI)
4				**Limiting Factors Assessed for Assessment Area = Channel Capacity and In-Channel Habitat (HQI = (V1+V2+V5)/3)**											
5	59	1	K0	BASE #1 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	0-4	N/A	219	0.10	0.21	N/A	N/A	0.17	0.16	24.5
6	59	1	K1	BASE #1 Complete Channel Capacity Dredging (RM 0-9) + LWD	Channel Capacity and In-Channel Habitat	0-4	N/A	219	0.93	0.93	N/A	N/A	1.00	0.95	208.7
7	***59***	***1***	***K1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***0-4***	***N/A***	***219***	***0.83***	***0.72***	***N/A***	***N/A***	***0.83***	***0.79***	***184.2***
8	50	2	L0	BASE # 2 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	4	N/A	26	0.10	0.21	N/A	N/A	0.17	0.16	*2.9*
9	50	2	L1	BASE #2 Confluence Channel Excavation + LWD	Channel Capacity and In-Channel Habitat	4	N/A	26	0.93	0.93	N/A	N/A	0.50	0.79	20.4
10	***50***	***2***	***L1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***4***	***N/A***	***26***	***0.83***	***0.72***	***N/A***	***N/A***	***0.33***	***0.63***	***17.5***
11	31	3	M0	BASE #3 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	4	N/A	68	0.10	0.21	N/A	N/A	0.17	0.16	*7.6*
12	31	3	M1	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal + LWD	Channel Capacity and In-Channel Habitat	4	N/A	68	0.93	0.93	N/A	N/A	0.50	0.79	*53.5*
13	***31***	***3***	***M1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***4***	***N/A***	***68***	***0.83***	***0.72***	***N/A***	***N/A***	***0.33***	***0.63***	***45.9***
14	62	5	N0	BASE #5 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	2-4	N/A	132	0.10	0.21	N/A	N/A	0.17	0.16	*14.8*
15	62	5	N1	BASE #5 RM 3.5-9 Dredge + LWD	Channel Capacity and In-Channel Habitat	2-4	N/A	132	0.93	0.93	N/A	N/A	1.00	0.95	*125.8*
16	***62***	***5***	***N1***	***Benefit (With-Without)***	***Channel Capacity and In-Channel Habitat***	***2-4***	***N/A***	***132***	***0.83***	***0.72***	***N/A***	***N/A***	***0.83***	***0.79***	***111.0***
17				**Limiting Factors Assessed for Assessment Area = Floodplain Habitat (HQI = (V3+V4)/2)**											
18	9	all	B0	River Channel Assessment Area Base/FWOP Condition	Floodplain Habitat	2-3	3	45	N/A	N/A	-	0.68	N/A	0.34	15.3
19	9	all	B1	River Channel	Floodplain Habitat	2-3	3	45	N/A	N/A	0.94	0.88	N/A	0.91	41.0
20	***9***	***all***	***B1***	***Benefit (With-Without)***	***Floodplain Habitat***	***2-3***	***3***	***45***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.57***	***25.7***
21	26	all	C0	Dips Road Assessment Area Base/FWOP Condition	Floodplain Habitat	4	4	17	N/A	N/A	-	0.40	N/A	0.20	3.4
22	26	all	C1	Dips Road	Floodplain Habitat	4	4	17	N/A	N/A	0.94	0.95	N/A	0.95	16.1
23	***26***	***all***	***C1***	***Benefit (With-Without)***	***Floodplain Habitat***	***4***	***4***	***17***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.75***	***12.7***
24	28	all	D0	Large Levee Setback Assessment Area Base/FWOP Condition	Floodplain Habitat	4	4	23	N/A	N/A	-	0.55	N/A	0.28	6.3
25	28	all	D1	Large Levee Setback	Floodplain Habitat	4	4	23	N/A	N/A	0.94	0.79	N/A	0.87	19.9
26	***28***	***all***	***D1***	***Benefit (With-Without)***	***Floodplain Habitat***	***4***	***4***	***23***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.59***	***13.6***
27	37	all	G0	Grange Dike Assessment Area Base/FWOP Condition	Floodplain Habitat	3-4	4	34	N/A	N/A	-	0.61	N/A	0.31	10.4
28	37	all	G1	Grange Dike	Floodplain Habitat	3-4	4	34	N/A	N/A	0.94	0.76	N/A	0.85	28.9
29	***37***	***all***	***G1***	***Benefit (With-Without)***	***Floodplain Habitat***	***3-4***	***4***	***34***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.54***	***18.5***
30	39	2 and 3	H0	Hunter Creek Mouth Assessment Area Base/FWOP Condition	Floodplain Habitat	3	3	0.5	N/A	N/A	-	0.81	N/A	0.41	0.2
31	39	2 and 3	H1	Hunter Creek Mouth	Floodplain Habitat	3	3	0.5	N/A	N/A	0.94	0.88	N/A	0.91	0.5
32	***39***	***2 and 3***	***H1***	***Benefit (With-Without)***	***Floodplain Habitat***	***3***	***3***	***0.5***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.51***	***0.3***
33	40	all	I0	Hunter Creek Assessment Area Base/FWOP Condition	Floodplain Habitat	3	3	29	N/A	N/A	-	0.10	N/A	0.05	1.5
34	40	all	I1	Hunter Creek Side Channel Habitat Reconnection	Floodplain Habitat	3	3	29	N/A	N/A	0.94	0.54	N/A	0.74	21.5
35	***40***	***all***	***I1***	***Benefit (With-Without)***	***Floodplain Habitat***	***3***	***3***	***29***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.69***	***20.1***
36				**Limiting Factors Assessed for Assessment Area = In-Channel Habitat (HQI = (V1+V2)/2)**											
37	35	all	F0	Upstream LWD Assessment Area Base/FWOP Condition	In-Channel Habitat	4-5	5	107	0.10	0.21	N/A	N/A	N/A	0.16	16.6
38	35	all	F1	Upstream LWD Installation	In-Channel Habitat	4-5	5	107	0.93	0.93	N/A	N/A	N/A	0.93	99.5
39	***35***	***all***	***F1***	***Benefit (With-Without)***	***In-Channel Habitat***	***4-5***	***5***	***107***	***0.83***	***0.72***	***N/A***	***N/A***	***N/A***	***0.77***	***82.9***
40	43	all	J0	Weaver Creek Assessment Area Base/FWOP Condition	In-Channel Habitat	3	3	25	0.10	0.21	N/A	N/A	N/A	0.16	3.9
41	43	all	J1	Weaver Creek Side Channel	In-Channel Habitat	3	3	25	0.93	0.93	N/A	N/A	N/A	0.93	23.2
42	***43***	***all***	***J1***	***Benefit (With-Without)***	***In-Channel Habitat***	***3***	***3***	***25***	***0.83***	***0.72***	***N/A***	***N/A***	***N/A***	***0.77***	***19.4***

	B	C	D	E	F	I	J	K	L	M	N	O	P
3	Project Number	Base # Assignment	Project Number/Base	Project Name	Assessment Area Limiting Factor(s)	Affected Acres	V1 – Woody Debris	V2 - Pools	V3 - Connectivity	V4 - Riparian Cover	V5 - Capacity	HQI	AAHU (Affected Acres * HQI)
4				Limiting Factors Assessed for Assessment Area = Channel Capacity and In-Channel Habitat (HQI = (V1+V2+V5)/3)									
5	59	1	K0	BASE #1 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	219	=IF(OR(F5="In-Channel Habitat",F5="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F5="In-Channel Habitat",F5="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F5="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F5="Floodplain Habitat",VLOOKUP(B5,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F5="Channel Capacity and In-Channel Habitat",VLOOKUP(C5,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F5="Channel Capacity and In-Channel Habitat",(J5+K5+N5)/3,IF(F5="In-Channel Habitat",(J5+K5)/2,IF(F5="Floodplain Habitat",(L5+M5)/2)))	=O5*I5
6	59	1	K1	BASE #1 Complete Channel Capacity Dredging (RM 0-9) + LWD	Channel Capacity and In-Channel Habitat	219	=IF(OR(F6="In-Channel Habitat",F6="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F6="In-Channel Habitat",F6="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F6="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F6="Floodplain Habitat",VLOOKUP(B6,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F6="Channel Capacity and In-Channel Habitat",VLOOKUP(C6,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F6="Channel Capacity and In-Channel Habitat",(J6+K6+N6)/3,IF(F6="In-Channel Habitat",(J6+K6)/2,IF(F6="Floodplain Habitat",(L6+M6)/2)))	=O6*I6
7	59	1	K1	Benefit (With-Without)	Channel Capacity and In-Channel Habitat	219	=IF(OR(F7="In-Channel Habitat",F7="Channel Capacity and In-Channel Habitat"),J6-J5,"N/A")	=IF(OR(F7="In-Channel Habitat",F7="Channel Capacity and In-Channel Habitat"),K6-K5,"N/A")	=IF(F7="Floodplain Habitat",L6-L5,"N/A")	=IF(F7="Floodplain Habitat",L6-L5,"N/A")	=IF(F7="Channel Capacity and In-Channel Habitat",N6-N5,"N/A")	=O6-O5	=O7*I7
8	50	2	L0	BASE # 2 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	26	=IF(OR(F8="In-Channel Habitat",F8="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F8="In-Channel Habitat",F8="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F8="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F8="Floodplain Habitat",VLOOKUP(B8,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F8="Channel Capacity and In-Channel Habitat",VLOOKUP(C8,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F8="Channel Capacity and In-Channel Habitat",(J8+K8+N8)/3,IF(F8="In-Channel Habitat",(J8+K8)/2,IF(F8="Floodplain Habitat",(L8+M8)/2)))	=O8*I8
9	50	2	L1	BASE #2 Confluence Channel Excavation + LWD	Channel Capacity and In-Channel Habitat	26	=IF(OR(F9="In-Channel Habitat",F9="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F9="In-Channel Habitat",F9="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F9="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F9="Floodplain Habitat",VLOOKUP(B9,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F9="Channel Capacity and In-Channel Habitat",VLOOKUP(C9,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F9="Channel Capacity and In-Channel Habitat",(J9+K9+N9)/3,IF(F9="In-Channel Habitat",(J9+K9)/2,IF(F9="Floodplain Habitat",(L9+M9)/2)))	=O9*I9
10	50	2	L1	Benefit (With-Without)	Channel Capacity and In-Channel Habitat	26	=IF(OR(F10="In-Channel Habitat",F10="Channel Capacity and In-Channel Habitat"),J9-J8,"N/A")	=IF(OR(F10="In-Channel Habitat",F10="Channel Capacity and In-Channel Habitat"),K9-K8,"N/A")	=IF(F10="Floodplain Habitat",L9-L8,"N/A")	=IF(F10="Floodplain Habitat",L9-L8,"N/A")	=IF(F10="Channel Capacity and In-Channel Habitat",N9-N8,"N/A")	=O9-O8	=O10*I10
11	31	3	M0	BASE #3 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	68	=IF(OR(F11="In-Channel Habitat",F11="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F11="In-Channel Habitat",F11="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F11="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F11="Floodplain Habitat",VLOOKUP(B11,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F11="Channel Capacity and In-Channel Habitat",VLOOKUP(C11,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F11="Channel Capacity and In-Channel Habitat",(J11+K11+N11)/3,IF(F11="In-Channel Habitat",(J11+K11)/2,IF(F11="Floodplain Habitat",(L11+M11)/2)))	=O11*I11
12	31	3	M1	BASE #3 North Fork/South Fork Confluence - Car Body Levee Removal + LWD	Channel Capacity and In-Channel Habitat	68	=IF(OR(F12="In-Channel Habitat",F12="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F12="In-Channel Habitat",F12="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F12="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F12="Floodplain Habitat",VLOOKUP(B12,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F12="Channel Capacity and In-Channel Habitat",VLOOKUP(C12,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F12="Channel Capacity and In-Channel Habitat",(J12+K12+N12)/3,IF(F12="In-Channel Habitat",(J12+K12)/2,IF(F12="Floodplain Habitat",(L12+M12)/2)))	=O12*I12
13	31	3	M1	Benefit (With-Without)	Channel Capacity and In-Channel Habitat	68	=IF(OR(F13="In-Channel Habitat",F13="Channel Capacity and In-Channel Habitat"),J12-J11,"N/A")	=IF(OR(F13="In-Channel Habitat",F13="Channel Capacity and In-Channel Habitat"),K12-K11,"N/A")	=IF(F13="Floodplain Habitat",L12-L11,"N/A")	=IF(F13="Floodplain Habitat",L12-L11,"N/A")	=IF(F13="Channel Capacity and In-Channel Habitat",N12-N11,"N/A")	=O12-O11	=O13*I13
14	62	5	N0	BASE #5 Assessment Area Base/FWOP Condition	Channel Capacity and In-Channel Habitat	132	=IF(OR(F14="In-Channel Habitat",F14="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F14="In-Channel Habitat",F14="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F14="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F14="Floodplain Habitat",VLOOKUP(B14,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F14="Channel Capacity and In-Channel Habitat",VLOOKUP(C14,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F14="Channel Capacity and In-Channel Habitat",(J14+K14+N14)/3,IF(F14="In-Channel Habitat",(J14+K14)/2,IF(F14="Floodplain Habitat",(L14+M14)/2)))	=O14*I14
15	62	5	N1	BASE #5 RM 3.5-9 Dredge + LWD	Channel Capacity and In-Channel Habitat	132	=IF(OR(F15="In-Channel Habitat",F15="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F15="In-Channel Habitat",F15="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F15="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F15="Floodplain Habitat",VLOOKUP(B15,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F15="Channel Capacity and In-Channel Habitat",VLOOKUP(C15,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F15="Channel Capacity and In-Channel Habitat",(J15+K15+N15)/3,IF(F15="In-Channel Habitat",(J15+K15)/2,IF(F15="Floodplain Habitat",(L15+M15)/2)))	=O15*I15
16	62	5	N1	Benefit (With-Without)	Channel Capacity and In-Channel Habitat	132	=IF(OR(F16="In-Channel Habitat",F16="Channel Capacity and In-Channel Habitat"),J15-J14,"N/A")	=IF(OR(F16="In-Channel Habitat",F16="Channel Capacity and In-Channel Habitat"),K15-K14,"N/A")	=IF(F16="Floodplain Habitat",L15-L14,"N/A")	=IF(F16="Floodplain Habitat",L15-L14,"N/A")	=IF(F16="Channel Capacity and In-Channel Habitat",N15-N14,"N/A")	=O15-O14	=O16*I16
17				Limiting Factors Assessed for Assessment Area = Floodplain Habitat (HQI = (V3+V4)/2)									
18	9	all	B0	River Channel Assessment Area Base/FWOP Condition	Floodplain Habitat	45	=IF(OR(F18="In-Channel Habitat",F18="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F18="In-Channel Habitat",F18="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F18="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F18="Floodplain Habitat",VLOOKUP(B18,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F18="Channel Capacity and In-Channel Habitat",VLOOKUP(C18,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F18="Channel Capacity and In-Channel Habitat",(J18+K18+N18)/3,IF(F18="In-Channel Habitat",(J18+K18)/2,IF(F18="Floodplain Habitat",(L18+M18)/2)))	=O18*I18
19	9	all	B1	River Channel	Floodplain Habitat	45	=IF(OR(F19="In-Channel Habitat",F19="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F19="In-Channel Habitat",F19="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F19="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F19="Floodplain Habitat",VLOOKUP(B19,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F19="Channel Capacity and In-Channel Habitat",VLOOKUP(C19,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F19="Channel Capacity and In-Channel Habitat",(J19+K19+N19)/3,IF(F19="In-Channel Habitat",(J19+K19)/2,IF(F19="Floodplain Habitat",(L19+M19)/2)))	=O19*I19
20	9	all	B1	Benefit (With-Without)	Floodplain Habitat	45	=IF(OR(F20="In-Channel Habitat",F20="Channel Capacity and In-Channel Habitat"),J19-J18,"N/A")	=IF(OR(F20="In-Channel Habitat",F20="Channel Capacity and In-Channel Habitat"),K19-K18,"N/A")	=IF(F20="Floodplain Habitat",L19-L18,"N/A")	=IF(F20="Floodplain Habitat",L19-L18,"N/A")	=IF(F20="Channel Capacity and In-Channel Habitat",N19-N18,"N/A")	=O19-O18	=O20*I20
21	26	all	C0	Dips Road Assessment Area Base/FWOP Condition	Floodplain Habitat	17	=IF(OR(F21="In-Channel Habitat",F21="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F21="In-Channel Habitat",F21="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F21="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F21="Floodplain Habitat",VLOOKUP(B21,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F21="Channel Capacity and In-Channel Habitat",VLOOKUP(C21,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F21="Channel Capacity and In-Channel Habitat",(J21+K21+N21)/3,IF(F21="In-Channel Habitat",(J21+K21)/2,IF(F21="Floodplain Habitat",(L21+M21)/2)))	=O21*I21
22	26	all	C1	Dips Road	Floodplain Habitat	17	=IF(OR(F22="In-Channel Habitat",F22="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F22="In-Channel Habitat",F22="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F22="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F22="Floodplain Habitat",VLOOKUP(B22,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F22="Channel Capacity and In-Channel Habitat",VLOOKUP(C22,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F22="Channel Capacity and In-Channel Habitat",(J22+K22+N22)/3,IF(F22="In-Channel Habitat",(J22+K22)/2,IF(F22="Floodplain Habitat",(L22+M22)/2)))	=O22*I22

	B	C	D	E	F	I	J	K	L	M	N	O	P
3	Project Number	Base # Assignment	Project Number/Base	Project Name	Assessment Area Limiting Factor(s)	Affected Acres	V1 – Woody Debris	V2 - Pools	V3 - Connectivity	V4 - Riparian Cover	V5 - Capacity	HQI	AAHU (Affected Acres * HQI)
23	26	all	C1	Benefit (With-Without)	Floodplain Habitat	17	=IF(OR(F23="In-Channel Habitat",F23="Channel Capacity and In-Channel Habitat"),J22-J21,"N/A")	=IF(OR(F23="In-Channel Habitat",F23="Channel Capacity and In-Channel Habitat"),K22-K21,"N/A")	=IF(F23="Floodplain Habitat",L22-L21,"N/A")	=IF(F23="Floodplain Habitat",L22-L21,"N/A")	=IF(F23="Channel Capacity and In-Channel Habitat",N22-N21,"N/A")	=O22-O21	=O23*I23
24	28	all	D0	Large Levee Setback Assessment Area Base/FWOP Condition	Floodplain Habitat	23	=IF(OR(F24="In-Channel Habitat",F24="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F24="In-Channel Habitat",F24="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F24="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F24="Floodplain Habitat",VLOOKUP(B24,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F24="Channel Capacity and In-Channel Habitat",VLOOKUP(C24,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F24="Channel Capacity and In-Channel Habitat",(J24+K24+N24)/3,IF(F24="In-Channel Habitat",(J24+K24)/2,IF(F24="Floodplain Habitat",(L24+M24)/2)))	=O24*I24
25	28	all	D1	Large Levee Setback	Floodplain Habitat	23	=IF(OR(F25="In-Channel Habitat",F25="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F25="In-Channel Habitat",F25="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F25="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F25="Floodplain Habitat",VLOOKUP(B25,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F25="Channel Capacity and In-Channel Habitat",VLOOKUP(C25,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F25="Channel Capacity and In-Channel Habitat",(J25+K25+N25)/3,IF(F25="In-Channel Habitat",(J25+K25)/2,IF(F25="Floodplain Habitat",(L25+M25)/2)))	=O25*I25
26	28	all	D1	Benefit (With-Without)	Floodplain Habitat	23	=IF(OR(F26="In-Channel Habitat",F26="Channel Capacity and In-Channel Habitat"),J25-J24,"N/A")	=IF(OR(F26="In-Channel Habitat",F26="Channel Capacity and In-Channel Habitat"),K25-K24,"N/A")	=IF(F26="Floodplain Habitat",L25-L24,"N/A")	=IF(F26="Floodplain Habitat",L25-L24,"N/A")	=IF(F26="Channel Capacity and In-Channel Habitat",N25-N24,"N/A")	=O25-O24	=O26*I26
27	37	all	G0	Grange Dike Assessment Area Base/FWOP Condition	Floodplain Habitat	34	=IF(OR(F27="In-Channel Habitat",F27="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F27="In-Channel Habitat",F27="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F27="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F27="Floodplain Habitat",VLOOKUP(B27,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F27="Channel Capacity and In-Channel Habitat",VLOOKUP(C27,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F27="Channel Capacity and In-Channel Habitat",(J27+K27+N27)/3,IF(F27="In-Channel Habitat",(J27+K27)/2,IF(F27="Floodplain Habitat",(L27+M27)/2)))	=O27*I27
28	37	all	G1	Grange Dike	Floodplain Habitat	34	=IF(OR(F28="In-Channel Habitat",F28="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F28="In-Channel Habitat",F28="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F28="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F28="Floodplain Habitat",VLOOKUP(B28,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F28="Channel Capacity and In-Channel Habitat",VLOOKUP(C28,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F28="Channel Capacity and In-Channel Habitat",(J28+K28+N28)/3,IF(F28="In-Channel Habitat",(J28+K28)/2,IF(F28="Floodplain Habitat",(L28+M28)/2)))	=O28*I28
29	37	all	G1	Benefit (With-Without)	Floodplain Habitat	34	=IF(OR(F29="In-Channel Habitat",F29="Channel Capacity and In-Channel Habitat"),J28-J27,"N/A")	=IF(OR(F29="In-Channel Habitat",F29="Channel Capacity and In-Channel Habitat"),K28-K27,"N/A")	=IF(F29="Floodplain Habitat",L28-L27,"N/A")	=IF(F29="Floodplain Habitat",L28-L27,"N/A")	=IF(F29="Channel Capacity and In-Channel Habitat",N28-N27,"N/A")	=O28-O27	=O29*I29
30	39	2 and 3	H0	Hunter Creek Mouth Assessment Area Base/FWOP Condition	Floodplain Habitat	0.5	=IF(OR(F30="In-Channel Habitat",F30="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F30="In-Channel Habitat",F30="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F30="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F30="Floodplain Habitat",VLOOKUP(B30,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F30="Channel Capacity and In-Channel Habitat",VLOOKUP(C30,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F30="Channel Capacity and In-Channel Habitat",(J30+K30+N30)/3,IF(F30="In-Channel Habitat",(J30+K30)/2,IF(F30="Floodplain Habitat",(L30+M30)/2)))	=O30*I30
31	39	2 and 3	H1	Hunter Creek Mouth	Floodplain Habitat	0.5	=IF(OR(F31="In-Channel Habitat",F31="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F31="In-Channel Habitat",F31="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F31="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F31="Floodplain Habitat",VLOOKUP(B31,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F31="Channel Capacity and In-Channel Habitat",VLOOKUP(C31,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F31="Channel Capacity and In-Channel Habitat",(J31+K31+N31)/3,IF(F31="In-Channel Habitat",(J31+K31)/2,IF(F31="Floodplain Habitat",(L31+M31)/2)))	=O31*I31
32	39	2 and 3	H1	Benefit (With-Without)	Floodplain Habitat	0.5	=IF(OR(F32="In-Channel Habitat",F32="Channel Capacity and In-Channel Habitat"),J31-J30,"N/A")	=IF(OR(F32="In-Channel Habitat",F32="Channel Capacity and In-Channel Habitat"),K31-K30,"N/A")	=IF(F32="Floodplain Habitat",L31-L30,"N/A")	=IF(F32="Floodplain Habitat",L31-L30,"N/A")	=IF(F32="Channel Capacity and In-Channel Habitat",N31-N30,"N/A")	=O31-O30	=O32*I32
33	40	all	I0	Hunter Creek Assessment Area Base/FWOP Condition	Floodplain Habitat	29	=IF(OR(F33="In-Channel Habitat",F33="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F33="In-Channel Habitat",F33="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F33="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F33="Floodplain Habitat",VLOOKUP(B33,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F33="Channel Capacity and In-Channel Habitat",VLOOKUP(C33,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F33="Channel Capacity and In-Channel Habitat",(J33+K33+N33)/3,IF(F33="In-Channel Habitat",(J33+K33)/2,IF(F33="Floodplain Habitat",(L33+M33)/2)))	=O33*I33
34	40	all	I1	Hunter Creek Side Channel Habitat Reconnection	Floodplain Habitat	29	=IF(OR(F34="In-Channel Habitat",F34="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F34="In-Channel Habitat",F34="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F34="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F34="Floodplain Habitat",VLOOKUP(B34,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F34="Channel Capacity and In-Channel Habitat",VLOOKUP(C34,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F34="Channel Capacity and In-Channel Habitat",(J34+K34+N34)/3,IF(F34="In-Channel Habitat",(J34+K34)/2,IF(F34="Floodplain Habitat",(L34+M34)/2)))	=O34*I34
35	40	all	I1	Benefit (With-Without)	Floodplain Habitat	29	=IF(OR(F35="In-Channel Habitat",F35="Channel Capacity and In-Channel Habitat"),J34-J33,"N/A")	=IF(OR(F35="In-Channel Habitat",F35="Channel Capacity and In-Channel Habitat"),K34-K33,"N/A")	=IF(F35="Floodplain Habitat",L34-L33,"N/A")	=IF(F35="Floodplain Habitat",L34-L33,"N/A")	=IF(F35="Channel Capacity and In-Channel Habitat",N34-N33,"N/A")	=O34-O33	=O35*I35
36				Limiting Factors Assessed for Assessment Area = In-Channel Habitat (HQI = (V1+V2)/2)									
37	35	all	F0	Upstream LWD Assessment Area Base/FWOP Condition	In-Channel Habitat	107	=IF(OR(F37="In-Channel Habitat",F37="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F37="In-Channel Habitat",F37="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F37="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F37="Floodplain Habitat",VLOOKUP(B37,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F37="Channel Capacity and In-Channel Habitat",VLOOKUP(C37,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F37="Channel Capacity and In-Channel Habitat",(J37+K37+N37)/3,IF(F37="In-Channel Habitat",(J37+K37)/2,IF(F37="Floodplain Habitat",(L37+M37)/2)))	=O37*I37
38	35	all	F1	Upstream LWD Installation	In-Channel Habitat	107	=IF(OR(F38="In-Channel Habitat",F38="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F38="In-Channel Habitat",F38="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F38="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F38="Floodplain Habitat",VLOOKUP(B38,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F38="Channel Capacity and In-Channel Habitat",VLOOKUP(C38,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F38="Channel Capacity and In-Channel Habitat",(J38+K38+N38)/3,IF(F38="In-Channel Habitat",(J38+K38)/2,IF(F38="Floodplain Habitat",(L38+M38)/2)))	=O38*I38
39	35	all	F1	Benefit (With-Without)	In-Channel Habitat	107	=IF(OR(F39="In-Channel Habitat",F39="Channel Capacity and In-Channel Habitat"),J38-J37,"N/A")	=IF(OR(F39="In-Channel Habitat",F39="Channel Capacity and In-Channel Habitat"),K38-K37,"N/A")	=IF(F39="Floodplain Habitat",L38-L37,"N/A")	=IF(F39="Floodplain Habitat",L38-L37,"N/A")	=IF(F39="Channel Capacity and In-Channel Habitat",N38-N37,"N/A")	=O38-O37	=O39*I39
40	43	all	J0	Weaver Creek Assessment Area Base/FWOP Condition	In-Channel Habitat	25	=IF(OR(F40="In-Channel Habitat",F40="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$7,"N/A")	=IF(OR(F40="In-Channel Habitat",F40="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$G$6,"N/A")	=IF(F40="Floodplain Habitat",'Assessment Metric HQI'!$G$15,"N/A")	=IF(F40="Floodplain Habitat",VLOOKUP(B40,'Assessment Metric HQI'!$E$8:$H$14,3),"N/A")	=IF(F40="Channel Capacity and In-Channel Habitat",VLOOKUP(C40,'Assessment Metric HQI'!$D$16:$I$19,4),"N/A")	=IF(F40="Channel Capacity and In-Channel Habitat",(J40+K40+N40)/3,IF(F40="In-Channel Habitat",(J40+K40)/2,IF(F40="Floodplain Habitat",(L40+M40)/2)))	=O40*I40

	B	C	D	E	F	I	J	K	L	M	N	O	P
3	**Project Number**	**Base # Assignment**	**Project Number/Base**	**Project Name**	**Assessment Area Limiting Factor(s)**	**Affected Acres**	**V1 – Woody Debris**	**V2 - Pools**	**V3 - Connectivity**	**V4 - Riparian Cover**	**V5 - Capacity**	**HQI**	**AAHU (Affected Acres * HQI)**
41	43	all	J1	Weaver Creek Side Channel	In-Channel Habitat	25	=IF(OR(F41="In-Channel Habitat",F41="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$7,"N/A")	=IF(OR(F41="In-Channel Habitat",F41="Channel Capacity and In-Channel Habitat"),'Assessment Metric HQI'!$H$6,"N/A")	=IF(F41="Floodplain Habitat",'Assessment Metric HQI'!$H$15,"N/A")	=IF(F41="Floodplain Habitat",VLOOKUP(B41,'Assessment Metric HQI'!$E$8:$H$14,4),"N/A")	=IF(F41="Channel Capacity and In-Channel Habitat",VLOOKUP(C41,'Assessment Metric HQI'!$D$16:$I$19,5),"N/A")	=IF(F41="Channel Capacity and In-Channel Habitat",(J41+K41+N41)/3,IF(F41="In-Channel Habitat",(J41+K41)/2,IF(F41="Floodplain Habitat",(L41+M41)/2)))	=O41*I41
42	***43***	***all***	***J1***	***Benefit (With-Without)***	***In-Channel Habitat***	***25***	***=IF(OR(F42="In-Channel Habitat",F42="Channel Capacity and In-Channel Habitat"),J41-J40,"N/A")***	***=IF(OR(F42="In-Channel Habitat",F42="Channel Capacity and In-Channel Habitat"),K41-K40,"N/A")***	***=IF(F42="Floodplain Habitat",L41-L40,"N/A")***	***=IF(F42="Floodplain Habitat",L41-L40,"N/A")***	***=IF(F42="Channel Capacity and In-Channel Habitat",N41-N40,"N/A")***	***=O41-O40***	***=O42*I42***

12 CE ICA SENSITIVITY ANALYSIS

This worksheet presents the sensitivity analysis from Section 8 of the main report. It evaluates the changes in HQI scores and overall AAHU benefits with weighting of one variable for each of the three HQI equations. The following weight changes to HQI equations were evaluated:

- $HQI = \frac{V1+V2+(2\times V5)}{4}$ for channel capacity and in-channel habitat where V5 (capacity) is twice as great as V1 (woody debris) and V2 (pools);
- $HQI = \frac{(2\times V1)+V2}{3}$ for in-channel habitat where V1 is twice as great as V2;
- $HQI = \frac{V1+(2\times V2)}{3}$ for in-channel habitat where V2 is twice as great as V1;
- $HQI = \frac{(2\times V3)+V4}{3}$ for floodplain habitat where V3 (connectivity) is twice as great as V4 (riparian cover); and
- $HQI = \frac{V3+(2\times V4)}{3}$ for floodplain habitat where V4 is twice as great as V3.

HQI scores and AAHUs for the weighting of metrics in the equations above are presented in columns Q through Y and are compared to the equal weighting of metrics for the three equations that will be used for evaluating the cost effectiveness and incremental cost analysis of project increments.

SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

APPENDIX G

ECONOMICS

DRAFT Integrated Feasibility Report and Environmental Impact Statement

US Army Corps of Engineers
Seattle District

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Tables

Figures

1. Overview

This appendix describes the cost effectiveness and incremental cost analysis (CE/ICA) performed for the Skokomish River Basin General Investigation (GI) draft integrated feasibility report and environmental impact statement (draft FR/EIS, or draft feasibility report). This process helps in the formulation of efficient and effective restoration solutions in the Skokomish River Basin. Because there is no currently accepted method for quantifying environmental benefits (or environmental outputs) in monetary terms, it is not possible to conduct a traditional benefit-cost analysis for the evaluation of project alternatives. Cost effectiveness and incremental cost analyses offer approaches that are consistent with the Principles and Guidelines (U.S. Water Resources Council, 1983; referred to as the “P&G”) planning paradigm. Cost effectiveness will ensure that the least cost solution is identified for each possible level of environmental output. Subsequent incremental cost analysis will reveal changes in cost for increasing levels of environmental outputs. While these analyses will usually not lead, and are not intended to lead, to a single best solution (as in economic benefit-cost analysis), they will improve the quality of decision making by ensuring that a rational, supportable, focused and traceable approach is used for considering and selecting alternatives for environmental restoration.

This report covers briefly summarizes some of the plan formulation and modeling of environmental outputs that focused the scope and inputs of the cost effectiveness and incremental cost analyses. The contents of this appendix are as follows:

- Section 2, Plan Formulation and Identification of Restoration Projects
- Section 3, Evaluation of Project Benefits
- Section 4, Evaluation of Project Costs
- Section 5, IWR Planning Suite Model Inputs
- Section 6, Cost Effectiveness and Incremental Cost Analysis (CE/ICA) Alternatives Evaluation
- Section 7, Final Array of Alternatives
- Section 8, Sensitivity Analysis
- Section 9, Tentatively Selected Plan (TSP)
- Section 10, References

2. Plan Formulation and Identification of Restoration Projects

The planning process which includes the identification of problems, opportunities, objectives and constraints, as well as the identification of management measures, siting of management measures, and screening is documented in Chapter 2 of draft feasibility report.

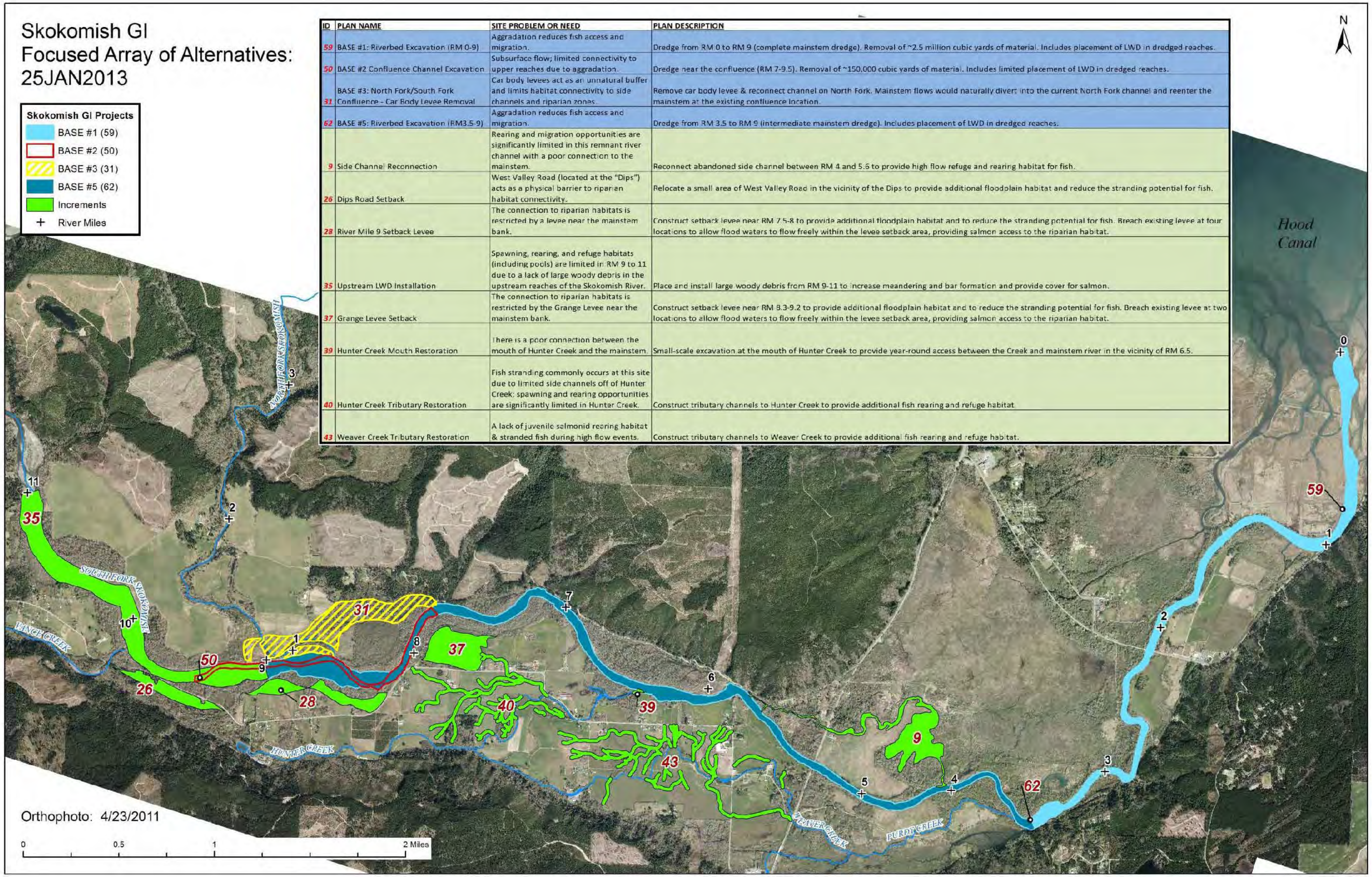
Based on the problems identified in the study area, planning objectives include the following:

- Provide year-round passage for fish species around the confluence of the North Fork and South Fork Skokomish River for the 50-year period of analysis.
- Reconnect and restore the spawning, rearing, and refuge habitats in the study's side channel and tributary networks including Hunter and Weaver Creeks for the 50-year period of analysis.
- Improve the quantity, quality, and complexity of native riparian and floodplain habitats in the study area for the 50-year period of analysis.
- Improve the quantity, quality, and complexity of pools in the Skokomish River to promote spawning and rearing success, as well as reduce stranding of ESA-listed salmonid species for the 50-year period of analysis.

The initial array of alternatives was formulated based on initial data collection and best professional judgment. This exercise led to the development of alternatives that include a "base" measure. The bases are key measures at specific sites or reaches of the river that address the highest priorities of the study area (improve the quantity, quality, and complexity of pools and provide a year-round channel for fish passage). The bases are large projects with no separable elements; they are also mutually exclusive from other bases. Developing alternatives around these base measures ensures the critical needs of the study area are addressed. An alternative cannot be considered complete, acceptable, efficient, or effective unless one of these bases is included. The bases include two large-scale sediment removal options that reach across multiple river reaches plus two smaller-scale restoration projects within specific reaches of the river.

Increments will be added to the focused array of four bases to capture supplementary benefits associated with restoration of additional channel and floodplain habitat features. These increments are generally smaller and can be combined with any of the base alternatives. Increments include in-channel habitat improvements which address the highest study priorities (increasing channel capacity and restoring year-round passage near the confluence). Finally, floodplain habitat increments were considered as lower priority restoration features. Potential floodplain increments include removal of blockages at the mouths of tributaries, restoration of side channel habitat, creation of new side channels, and levee setbacks.

Of the approximately 60 potential restoration sites, eight sites were identified by the study team as high priority in-channel or floodplain increments that in combination with one of the bases would address restoration needs in the basin. Key information about the bases and increments are described in the draft feasibility report. A map of the focused array of bases and potential increments is shown in Figure 2-1.



ID	PLAN NAME	SITE PROBLEM OR NEED	PLAN DESCRIPTION
59	BASE #1: Riverbed Excavation (RM 0-9)	Aggradation reduces fish access and migration.	Dredge from RM 0 to RM 9 (complete mainstem dredge). Removal of ~2.5 million cubic yards of material. Includes placement of LWD in dredged reaches.
50	BASE #2 Confluence Channel Excavation	Subsurface flow; limited connectivity to upper reaches due to aggradation.	Dredge near the confluence (RM 7-9.5). Removal of ~150,000 cubic yards of material. Includes limited placement of LWD in dredged reaches.
31	BASE #3: North Fork/South Fork Confluence - Car Body Levee Removal	Car body levees act as an unnatural buffer and limits habitat connectivity to side channels and riparian zones.	Remove car body levee & reconnect channel on North Fork. Mainstem flows would naturally divert into the current North Fork channel and reenter the mainstem at the existing confluence location.
62	BASE #5: Riverbed Excavation (RM3.5-9)	Aggradation reduces fish access and migration.	Dredge from RM 3.5 to RM 9 (intermediate mainstem dredge). Includes placement of LWD in dredged reaches.
9	Side Channel Reconnection	Rearing and migration opportunities are significantly limited in this remnant river channel with a poor connection to the mainstem.	Reconnect abandoned side channel between RM 4 and 5.6 to provide high flow refuge and rearing habitat for fish.
26	Dips Road Setback	West Valley Road (located at the "Dips") acts as a physical barrier to riparian habitat connectivity.	Relocate a small area of West Valley Road in the vicinity of the Dips to provide additional floodplain habitat and reduce the stranding potential for fish.
28	River Mile 9 Setback Levee	The connection to riparian habitats is restricted by a levee near the mainstem bank.	Construct setback levee near RM 7.5-8 to provide additional floodplain habitat and to reduce the stranding potential for fish. Breach existing levee at four locations to allow flood waters to flow freely within the levee setback area, providing salmon access to the riparian habitat.
35	Upstream LWD Installation	Spawning, rearing, and refuge habitats (including pools) are limited in RM 9 to 11 due to a lack of large woody debris in the upstream reaches of the Skokomish River.	Place and install large woody debris from RM 9-11 to increase meandering and bar formation and provide cover for salmon.
37	Grange Levee Setback	The connection to riparian habitats is restricted by the Grange Levee near the mainstem bank.	Construct setback levee near RM 8.3-9.2 to provide additional floodplain habitat and to reduce the stranding potential for fish. Breach existing levee at two locations to allow flood waters to flow freely within the levee setback area, providing salmon access to the riparian habitat.
39	Hunter Creek Mouth Restoration	There is a poor connection between the mouth of Hunter Creek and the mainstem.	Small-scale excavation at the mouth of Hunter Creek to provide year-round access between the Creek and mainstem river in the vicinity of RM 6.5.
40	Hunter Creek Tributary Restoration	Fish stranding commonly occurs at this site due to limited side channels off of Hunter Creek; spawning and rearing opportunities are significantly limited in Hunter Creek.	Construct tributary channels to Hunter Creek to provide additional fish rearing and refuge habitat.
43	Weaver Creek Tributary Restoration	A lack of juvenile salmonid rearing habitat & stranded fish during high flow events.	Construct tributary channels to Weaver Creek to provide additional fish rearing and refuge habitat.

Figure 2-1. Focused Array of Bases and Potential Increments

3. Evaluation of Project Benefits

The study team developed an environmental outputs model (EO Model) to estimate benefits of proposed restoration actions in the Skokomish GI. This model was approved for one-time use approval in October 2013. The model documentation, including the biological and ecological rationale and quantification of benefits can be found in Appendix F, Ecosystem Benefits Model Documentation.

For each proposed restoration action, it was first determined whether the project assessment area for that action would result in measureable change to the channel capacity, in-channel habitat, or floodplain habitat limiting factors. After determining applicable limiting factor(s) for a project assessment area, the without project and with project habitat quality index scores for relevant assessment metrics were estimated. Two assessment metrics were used for in-channel habitat: woody debris (V1) and pools (V2). Two assessment metrics were used for floodplain habitat: connectivity (V3) and riparian cover (V4). Finally, channel capacity was measured using a flow capacity (V5) assessment metric. Three equations were used to estimate habitat quality indices based on the applicable limiting factors. A project that would address in-channel habitat only would be evaluated using the in-channel habitat assessment metrics for woody debris and pools. The bases address both in-channel habitat and channel capacity limiting factors. Figure 3-1 includes a flow diagram of which assessment metrics (labeled V1 to V5) are considered in the computation of HQI for a restoration action based on the assessment area limiting factor(s).

HQI is equal to one of three equations depending on the limiting factor(s) that apply to a given assessment area:

- $HQI = \frac{V1+V2+V5}{3}$ for assessment areas which evaluate both channel capacity and in-channel habitat limiting factors;
- $HQI = \frac{V1+V2}{2}$ for assessment areas which evaluate the in-channel habitat limiting factor only; and
- $HQI = \frac{V3+V4}{2}$ for assessment areas that evaluate the floodplain habitat limiting factor only.

AAHUs are computed for an assessment area by multiplying the HQI given the applicable limiting factor(s) and the affected acres as follows:

$$AAHU = HQI \; x \; Affected \; Area$$

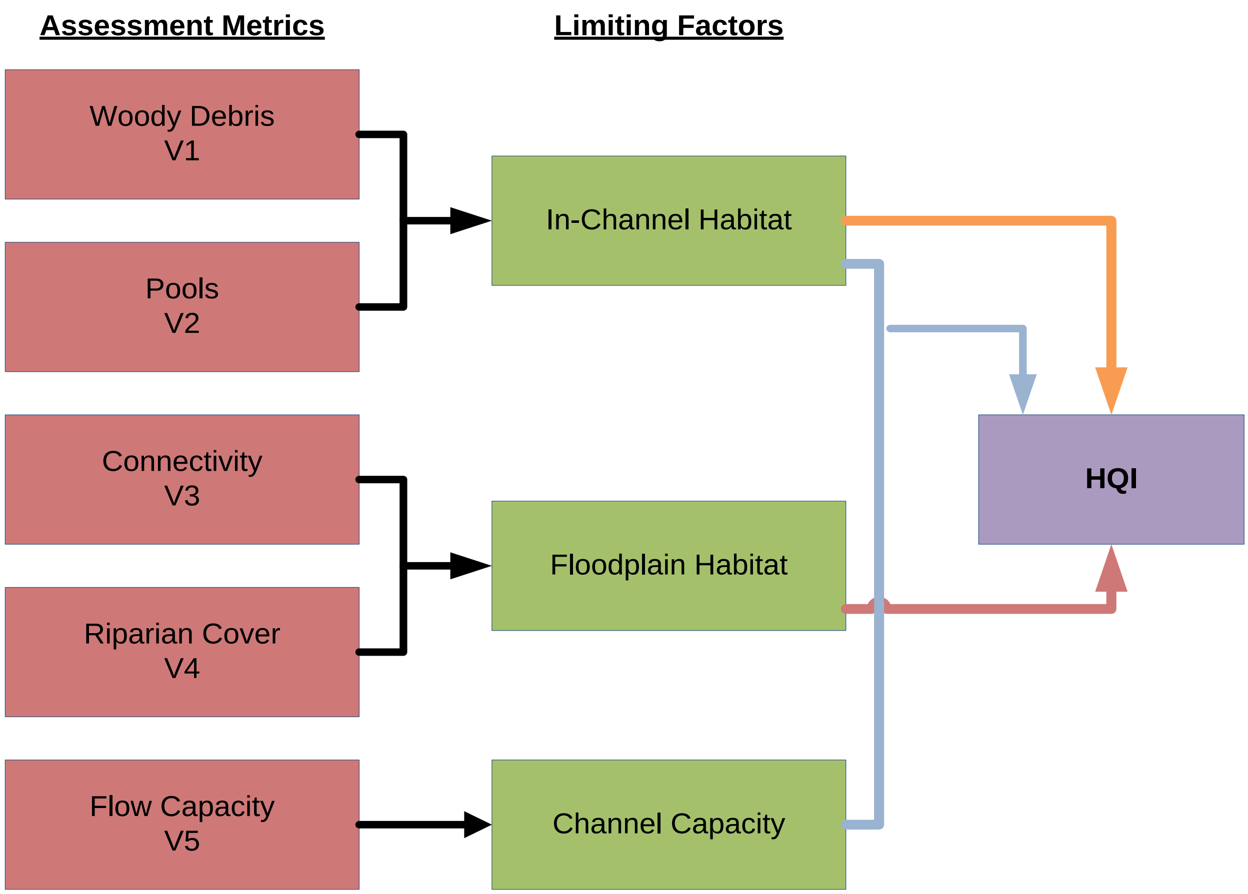


Figure 3-1. Flow Diagram of HQI Computation Based on Assessment Area Limiting Factor(s) and Assessment Metrics

Table 3-1 displays the evaluation of assessment areas by the limiting factor(s) the proposed project increments address. For each assessment area, three evaluations are presented. The first line is the evaluation of the without project condition for the assessment areas and is denoted by a letter followed by 0. It is scored based on the applicable limiting factor(s) and HQI is computed using the applicable HQI equation. The second line is for the project increment (with-project action) and is denoted with the same project letter followed by 1. It evaluates the habitat quality associated with the proposed action and is scored using the same assessment metrics used in the without project condition. Lastly, the third line presents the benefits of the proposed action. The benefits are taken as the change in HQI score multiplied by the affected area of the project.

$$Benefits\ (in\ AAHU) = Change\ in\ HQI\ Score\ (With\ Project - Without\ Project)\ x\ Affected\ Area$$

Table 3-1. EO Model Benefits for Assessment Areas with Channel Capacity and In-Channel Habitat Limiting Factors (Bases)

Quality Index Scores for Applicable Variables									
Project Number	**Project ID**	**Affected Acres**	**V1 - Woody Debris**	**V2 - Pools**	**V3 - Connectivity**	**V4 - Riparian Cover**	**V5 - Capacity**	**HQI**	**AAHU (Affected Acres * HQI)**
Bases: Limiting Factors for Assessment Area = Channel Capacity and In-Channel Habitat HQI = (V1 + V2 + V5)/3									
59	K0	219	0.1	0.21	N/A	N/A	0.03	0.11	24.5
59	K1	219	0.93	0.93	N/A	N/A	1	0.95	208.7
59	***K1***	***219***	***0.83***	***0.72***	***N/A***	***N/A***	***0.97***	***0.84***	***184.2***
50	L0	26	0.1	0.21	N/A	N/A	0.03	0.11	*2.9*
50	L1	26	0.93	0.93	N/A	N/A	0.5	0.79	20.4
50	***L1***	***26***	***0.83***	***0.72***	***N/A***	***N/A***	***0.47***	***0.67***	***17.5***
31	M0	68	0.1	0.21	N/A	N/A	0.03	0.11	*7.6*
31	M1	68	0.93	0.93	N/A	N/A	0.5	0.79	*53.5*
31	***M1***	***68***	***0.83***	***0.72***	***N/A***	***N/A***	***0.47***	***0.67***	***45.9***
62	N0	132	0.1	0.21	N/A	N/A	0.03	0.11	*14.8*
62	N1	132	0.93	0.93	N/A	N/A	1	0.95	*125.8*
62	***N1***	***132***	***0.83***	***0.72***	***N/A***	***N/A***	***0.97***	***0.84***	***111***
In-Channel Increments: Limiting Factors for Assessment Area = In-Channel Habitat HQI = (V1 + V2) / 2									
35	F0	107	0.1	0.21	N/A	N/A	N/A	0.16	16.6
35	F1	107	0.93	0.93	N/A	N/A	N/A	0.93	99.5
35	***F1***	***107***	***0.83***	***0.72***	***N/A***	***N/A***	***N/A***	***0.77***	***82.9***
43	J0	25	0.1	0.21	N/A	N/A	N/A	0.16	3.9
43	J1	25	0.93	0.93	N/A	N/A	N/A	0.93	23.2
43	***J1***	***25***	***0.83***	***0.72***	***N/A***	***N/A***	***N/A***	***0.77***	***19.4***
Floodplain Increments: Limiting Factors for Assessment Area = Floodplain Habitat HQI = (V3 + V4) / 2									
9	B0	45	N/A	N/A	-	0.68	N/A	0.34	15.3
9	B1	45	N/A	N/A	0.94	0.88	N/A	0.91	41
9	***B1***	***45***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.57***	***25.7***
26	C0	17	N/A	N/A	-	0.4	N/A	0.2	3.4
26	C1	17	N/A	N/A	0.94	0.95	N/A	0.95	16.1
26	***C1***	***17***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.75***	***12.7***
28	D0	23	N/A	N/A	-	0.55	N/A	0.28	6.3
28	D1	23	N/A	N/A	0.94	0.79	N/A	0.87	19.9
28	***D1***	***23***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.59***	***13.6***
37	G0	34	N/A	N/A	-	0.61	N/A	0.31	10.4
37	G1	34	N/A	N/A	0.94	0.76	N/A	0.85	28.9
37	***G1***	***34***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.54***	***18.5***
39	H0	0.5	N/A	N/A	-	0.81	N/A	0.41	0.2
39	H1	0.5	N/A	N/A	0.94	0.88	N/A	0.91	0.5
39	***H1***	***0.5***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.51***	***0.3***
40	I0	29	N/A	N/A	-	0.1	N/A	0.05	1.5
40	I1	29	N/A	N/A	0.94	0.54	N/A	0.74	21.5
40	***I1***	***29***	***N/A***	***N/A***	***0.94***	***0.94***	***N/A***	***0.69***	***20.1***

With any attempt to quantify environmental benefits, the method will have inherent uncertainties and limitations. These model limitations and uncertainties are described in Appendix F, Ecosystem Benefits Model Documentation.

As the study team developed conceptual designs and cost estimates for the bases, a number of disposal options were identified for the riverbed excavation bases. Placement of dredged material in the estuary and nearshore area of the Skokomish River was identified as the most likely disposal option (other options included disposal in a nearby quarry or open-water disposal). Placement of dredged material in approximately 800 acres of the estuary would create high quality shellfish habitat (e.g., hard substrate for oyster attachment) and would significantly reduce costs associated with transportation and disposal of up to 2.5 million cubic yards of dredged material outside of the study area.

It should be noted that the environmental benefits model did not formally account for the benefits associated with placing dredged material in the estuary for shellfish attachment; the model only captures benefits related to channel habitat quality, floodplain habitat connectivity, and mainstem river channel capacity. To capture the approximate benefits associated with placement of hard substrate in the estuary for shellfish habitat, the study team developed a conservative estimate for the habitat quality change in the estuary and nearshore (0.25) that would result from placement of dredged material. This habitat quality score was multiplied by the affected area shown in Table 3-2 (511 acres for Base #5 and 843 acres for Base #1). These outputs are presented as “AAHU (Shellfish Substrate)” in Table 3-3.

Table 3-2. Base Benefits

Base	Affected Area Benefits (Channel Benefits)	Approximate Affected Area for Beneficial Use for Shellfish Substrate (Shellfish Benefits)	Improvement of Egg-to-Fry Survival (+/-%)
No Action	0 acres	0 acres	No Change
Base #2	26 acres	0 acres	No Change
Base #3	68 acres	0 acres	No Change
Base #5	132 acres	511 acres	+30%
Base #1	219 acres	843 acres	+52%

Average annual habitat units (AAHU’s) calculated by the environmental benefits model (presented as “AAHU (EO Model)” in Table 3-3) were added to habitat units calculated outside of the EO model (shellfish substrate) to determine total habitat units. The total outputs are presented as “Total AAHU” in Table 3-3.

It should also be noted that the sediment excavation bases (Bases #1 and #5) improve egg-to-fry survival by reducing the frequency of flooding from four or more times annual to once every one to two years. Over the 50 year period of analysis, Base #1 and Base #5 are expected to show 52 percent and 30 percent improvement in egg-to-fry survival, respectively, as shown in Table 3-2. These benefits were not directly incorporated in to the cost effectiveness and incremental cost analyses. Rather, channel capacity improvements are included in the EO model which examines changes to flood flow capacity.

For the purposes of comparing and evaluating alternatives, the AAHU's presented in Table 3-3 will be used in IWR Planning Suite (USACE certified version 2.0.6.0) to evaluate the cost effectiveness and incremental cost of the bases in combinations with the additional incremental projects. Total AAHU's for incremental projects are equal to the difference in AAHU's for the without-project condition and the with-project condition for a given assessment area.

Table 3-3. Revised Environmental Outputs by Restoration Project

Project Number	Base Combinability	Project ID	Project Name	Total Acres Affected	AAHU (EO Model)	AAHU (Shellfish Substrate)	Total AAHU
59	1	K1	Base #1: Riverbed Excavation (RM 0-9)	219 + 843 shellfish = 1,062	184.2	210.8	395.0
50	2	L1	Base #2: Confluence Channel Excavation	26	17.5	n/a	17.5
31	3	M1	Base #3: Car Body Levee Removal	68	45.9	n/a	45.9
62	5	N1	Base #5: Riverbed Excavation (RM 3.5-9)	132 + 219 shellfish = 643	111.0	127.8	238.8
9	all	B1	Side Channel Reconnection	45	25.7	n/a	25.7
26	all	C1	Dips Road Setback	17	12.7	n/a	12.7
28	all	D1	River Mile 9 Levee Setback	23	13.6	n/a	13.6
35	all	F1	Upstream LWD Installation	107	82.9	n/a	82.9
37	all	G1	Grange Levee Setback	34	18.5	n/a	18.5
39	2 and 3	H1	Hunter Creek Tributary Mouth Restoration	0.5	0.3	n/a	0.3
40	all	I1	Hunter Creek Tributary Reconnection	29	20.1	n/a	20.1
43	all	J1	Weaver Creek Tributary Reconnection	25	19.4	n/a	19.4

4. Evaluation of Project Costs

Table 4-1shows the present value construction and real estate costs, computed interest during construction (IDC), periodic operations and maintenance (O&M) costs, and total investment costs and annualized costs for each base and increment. O&M was assumed to be minimal for each of the increments, with exception of the excavation bases (Bases #1, #2, and #5). Periodic sediment excavation would be required to maintain channel capacity and is estimated to occur every 20 years for Bases #1 and #5, or for two cycles during the period of analysis (in years 20 and 40), and every 10 years for Base #2, or five cycles during the period of analysis (in years 10, 20, 30, 40, and 50). Planning level cost estimates were developed for the purposes of alternative formulation and comparison. Additional cost information can be found in Appendix K, *Cost Estimate*. Costs were annualized using the IWR Planning Suite Annualization Tool (USACE certified version 2.0.6.0) using the construction cost, real estate cost, construction period (in months) for IDC computations, estimated O&M, the current discount rate (the fiscal year 2013 discount rate is 3.75 percent), and a 50 year period of analysis.

Table 4-1. Average Annual Cost of Bases and Increments

Project Number	Project Name	Construction Cost (1,000s)	Real Estate Cost Estimate ($1,000s)	Interest During Constructio n ($1,000s)	Total Investment Cost ($1,000s)	Cost for periodic O&M / Frequency	Total Average Annual Cost ($1,000s)
59	Base #1: Riverbed Excavation (RM 0-9)	$141,391	$2	$7,173	$148,567	$43.4 M / Every 20 years (2x)	$8,035
50	Base #2: Confluence Channel Excavation	$14,017	$2	$65	$14,084	$6.2 M / Every 10 years (5x)	$1,153
31	Base #3: Car Body Levee Removal	$6,721	$741	$62	$7,525		$335
62	Base #5: Riverbed Excavation (RM 3.5-9)	$94,756	$2	$2,816	$97,575	$38.0 M / Every 20 years (2x)	$5,548
9	Side Channel Reconnection	$1,024	$2,069	$3	$3,096		$138
26	Dips Road Setback	$5,148	$97	$40	$5,285		$236,
28	River Mile 9 Levee Setback	$2,250	$101	$14	$2,365		$105
35	Upstream LWD Installation	$870	$2,357	$3	$3,229		$144
37	Grange Levee Setback	$2,722	$538	$17	$3,277		$146
39	Hunter Creek Tributary Mouth	$11	$193	$0	$204		$9
40	Hunter Creek Tributary Reconnection	$4,190	$1,100	$13	$5,303		$236
43	Weaver Creek Tributary Reconnection	5,318	$2,261	$25	$7,603		$339

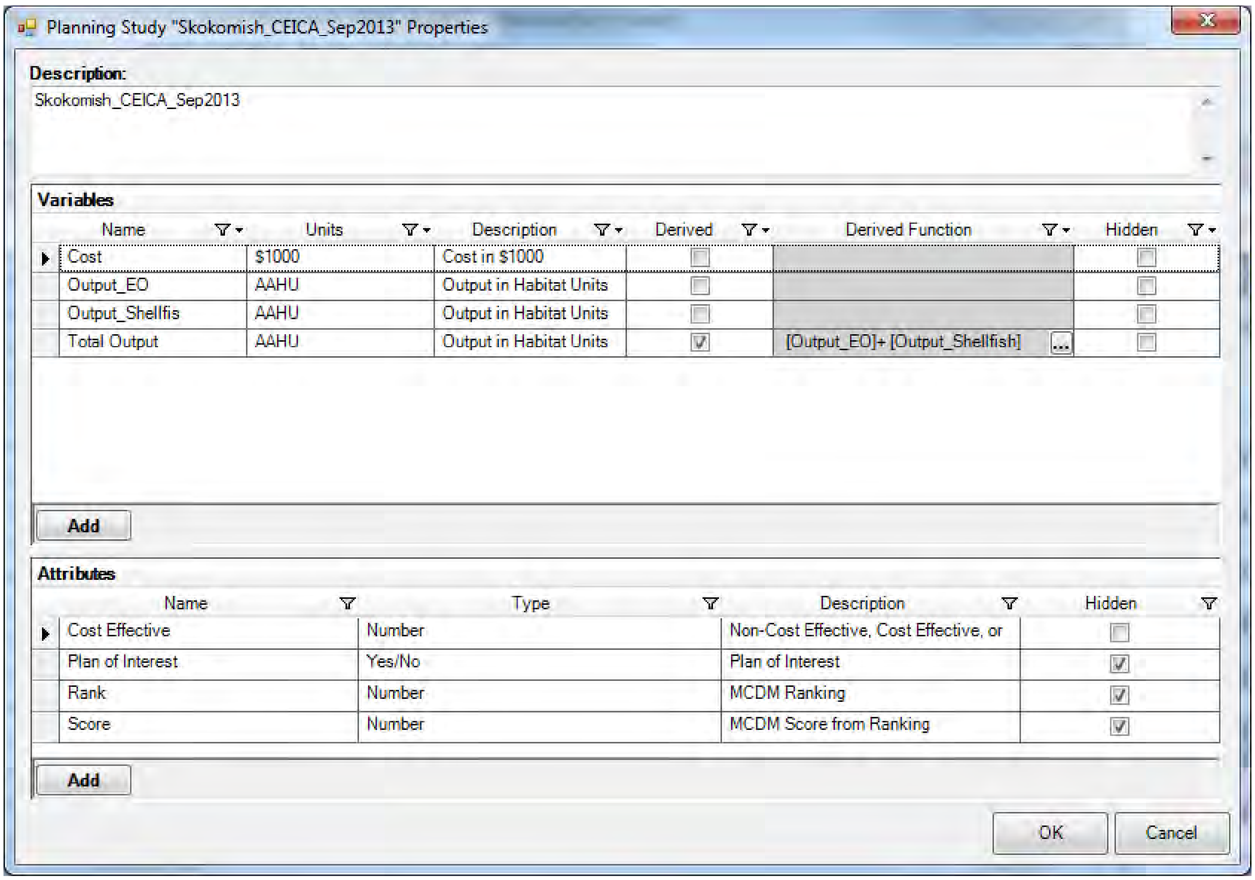
5. IWR Planning Suite Model Inputs for Cost Effectiveness and Incremental Cost Analyses

This section describes the model inputs for performing the cost effectiveness and incremental cost analyses using the IWR Planning Suite, version 2.0.6.0 (USACE certified model). The USACE Institute for Water Resources (IWR) developed this software to assist with the formulation and comparison of alternative plans. The software can assist with plan formulation by combining solutions to planning problems and calculating the additive effect of each combination, or “plan”, by utilizing inputs on outputs (AAHU’s), costs, and rules (combinability and dependency relationships) for combining solutions into plans. Plans are then compared in IWR Planning Suite by conducting cost effectiveness and incremental cost analyses (CE/ICA), identifying the plans which are the best financial investments, and displaying the effects of each on a range of decision variables. The cost effectiveness and incremental cost analyses are presented in Section 6.

5.1 Planning Study Properties

Figure 5-1displays the study variables for the cost effectiveness and incremental cost analysis. Cost is input as an annual cost in $1,000s. Two output scores are input Average Annual Habitat Units (AAHU), one for the Environmental Outputs Model AAHU's ("Output_EO") and one for shellfish substrate ("Output_Shellfis"). Total output ("Total Output") is derived by adding together two output scores ("[Output_EO] + [Output_Shellfish]"), and is also measured in AAHU's.

Figure 5-1. Planning Study Properties



5.2 Solutions and Scales

Four bases and eight project increments were input into IWR Planning Suite as shown in Figure 5-2. Along with the project name, other inputs for the bases and project increments include the average annual cost ("Cost" column, derived using the Annualizer in IWR Planning Suite), AAHU's derived from the Environmental Outputs Model ("Output_EO"), and AAHU's estimated for shellfish substrate associated with dredged material placement for Bases #1 and #5 ("Output_Shellfis"). Each unique project is assigned a code letter (i.e. Base #1 is code "K"). Each project has a No Action cost and output equal to zero. The output for the action is gain in output (AAHU's) to be realized with implementation of the proposed project as compared to the No Action.

Figure 5-2. Solutions and Scales

Solutions and Scales

Solutions

Solution	Code	# Scales
Base Alternative #1: Riverbed Excavation (RM 0-9)	K	1
Base Alternative #5: Riverbed Excavation (RM 3.5-9	N	1
Base Alternative #2: Confluence Channel Excavation	L	1
Base Alternative #3: Car Body Levee Removal	M	1
Increment #9: Side Channel Reconnection	B	1
Increment #26: Dips Road Setback	C	1
Increment #28: River Mile 9 Levee Setback	D	1
Increment #35: Upstream LWD Installation	F	1
Increment #37: Grange Levee Setback	G	1
Increment #39: Hunter Creek Tributary Mouth	H	1
Increment #40: Hunter Creek Tributary Restoration	I	1

Add

Scaled Solution Effects on Variables

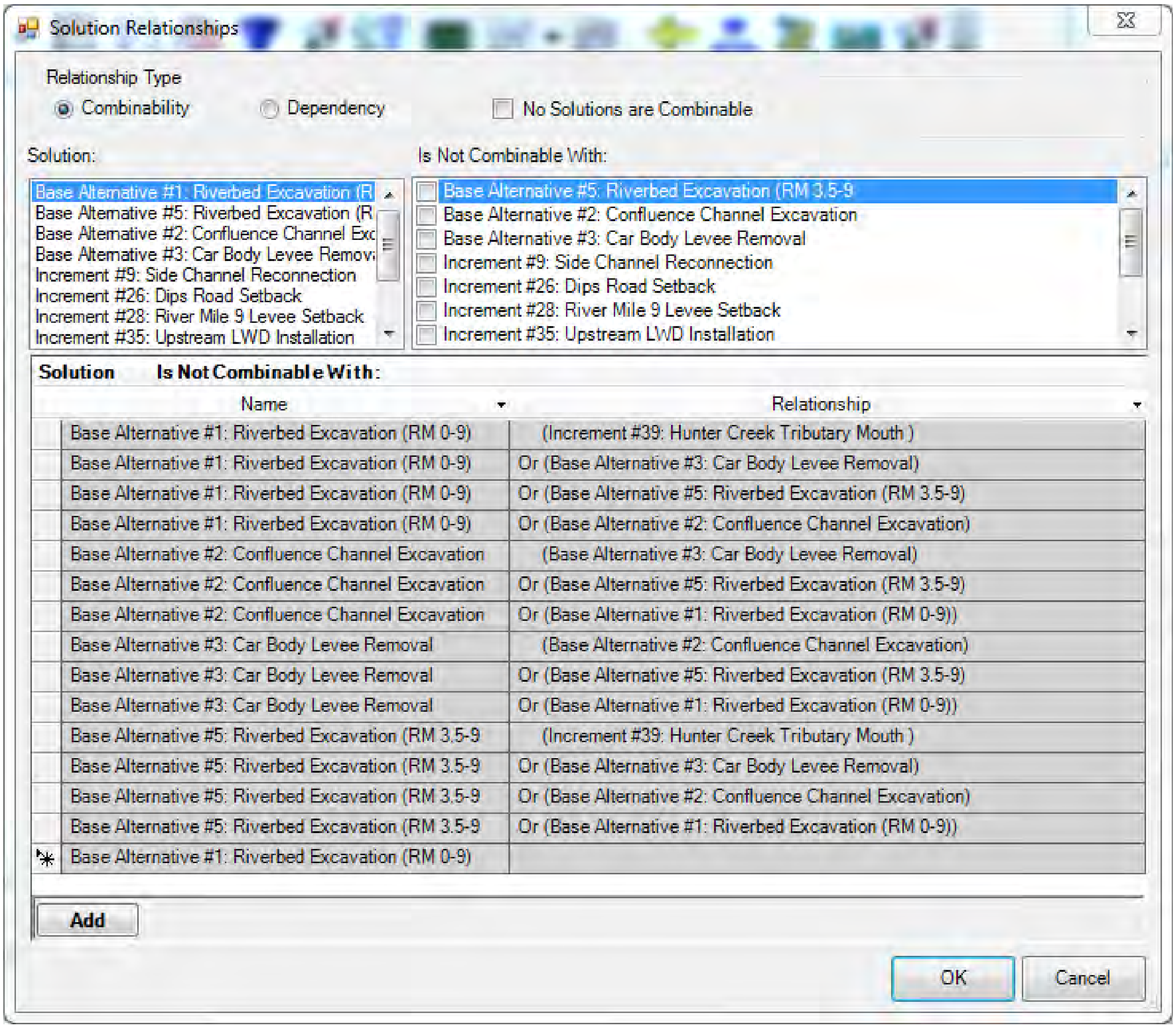
Cod		Name	Cost	Output_EO	Output_Shellfis
K	0	No Action	0	0	0
K	1	Base Alternative #1: Riverbed Excavation (RM 0-9)	8035	184.2	210.8
N	0	No Action	0	0	0
N	1	Base Alternative #5: Riverbed Excavation (RM 3.5-9	5548	111	127.8
L	0	No Action	0	0	0
L	1	Base Alternative #2: Confluence Channel Excavation	1153	17.5	0
M	0	No Action	0	0	0
M	1	Base Alternative #3: Car Body Levee Removal	335	45.9	0
B	0	No Action	0	0	0
B	1	Increment #9: Side Channel Reconnection	138	25.7	0
C	0	No Action	0	0	0
C	1	Increment #26: Dips Road Setback	236	12.7	0
D	0	No Action	0	0	0
D	1	Increment #28: River Mile 9 Levee Setback	105	13.6	0
F	0	No Action	0	0	0
F	1	Increment #35: Upstream LWD Installation	144	82.9	0
G	0	No Action	0	0	0
G	1	Increment #37: Grange Levee Setback	146	18.5	0
H	0	No Action	0	0	0
H	1	Increment #39: Hunter Creek Tributary Mouth	9	0.3	0
I	0	No Action	0	0	0
I	1	Increment #40: Hunter Creek Tributary Restoration	236	20.1	0
J	0	No Action	0	0	0
J	1	Increment #43: Weaver Creek Tributary Restoration	339	19.4	0

OK Cancel

5.3 Solution Relationships – Combinability

Combinability relationships were input in IWR Planning Suite as shown in Figure 5-3. Generally all solutions are combinable, with exception to the bases. No bases may be combined with any other base.

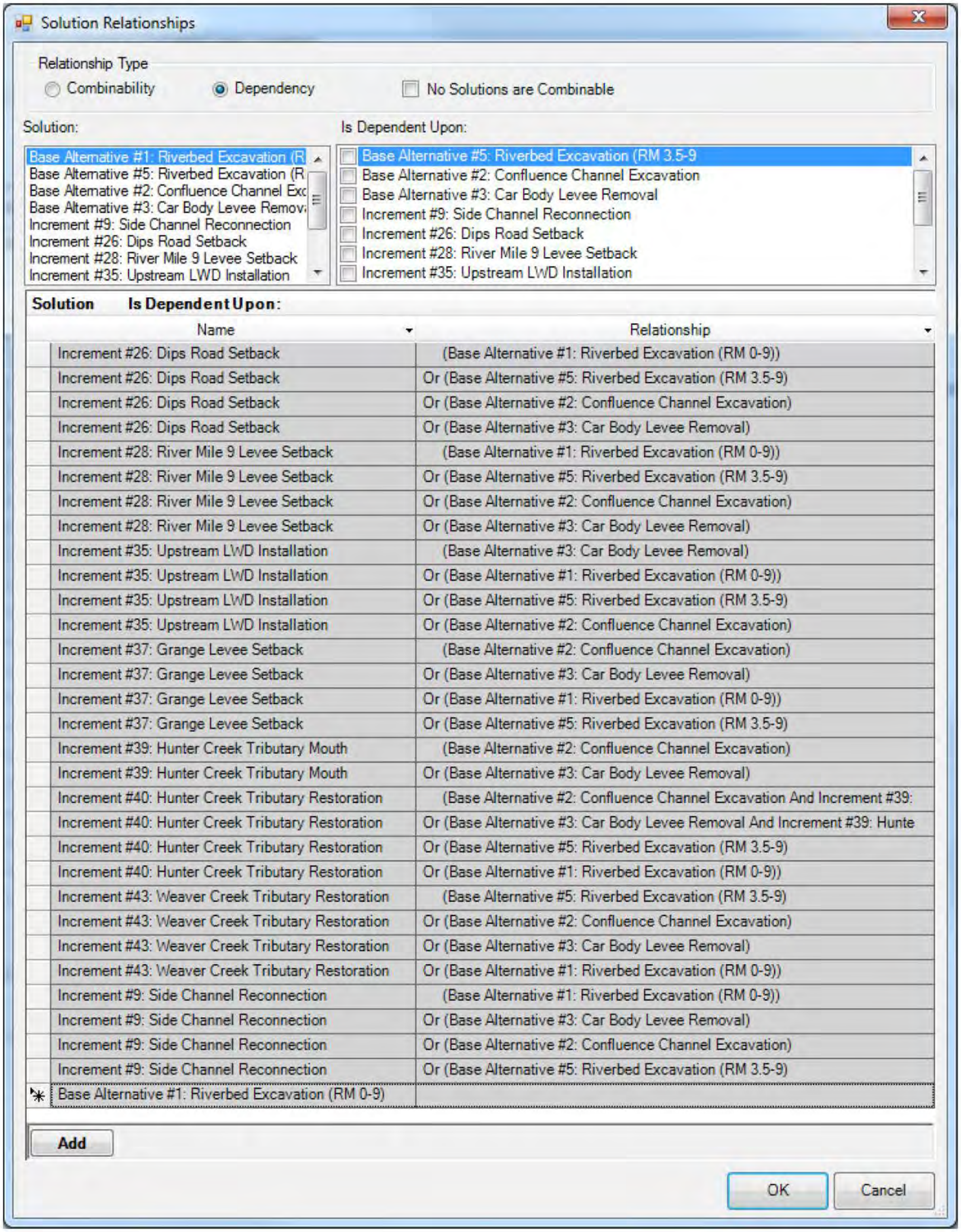
Figure 5-3. Solution Relationships – Combinability



5.4 Solution Relationships – Dependency

Dependency relationships were input in IWR Planning Suite as shown in Figure 5-4. Each incremental project is dependent on a base. Increment #40, Weaver Creek Tributary Restoration, is dependent on Increment #39, Hunter Creek Tributary Mouth, when combined with Base #2, Confluence Channel Excavation, and Base #3, Car Body Levee Removal. The mouth of Hunter Creek Tributary is assumed to be addressed by the excavation associated with Bases #1, Riverbed Excavation (River Mile 0-9), and #5, Riverbed Excavation (RM 3.5-9).

Figure 5-4. Solution Relationships – Dependency



Name	Relationship
Increment #26: Dips Road Setback	(Base Alternative #1: Riverbed Excavation (RM 0-9))
Increment #26: Dips Road Setback	Or (Base Alternative #5: Riverbed Excavation (RM 3.5-9)
Increment #26: Dips Road Setback	Or (Base Alternative #2: Confluence Channel Excavation)
Increment #26: Dips Road Setback	Or (Base Alternative #3: Car Body Levee Removal)
Increment #28: River Mile 9 Levee Setback	(Base Alternative #1: Riverbed Excavation (RM 0-9))
Increment #28: River Mile 9 Levee Setback	Or (Base Alternative #5: Riverbed Excavation (RM 3.5-9)
Increment #28: River Mile 9 Levee Setback	Or (Base Alternative #2: Confluence Channel Excavation)
Increment #28: River Mile 9 Levee Setback	Or (Base Alternative #3: Car Body Levee Removal)
Increment #35: Upstream LWD Installation	(Base Alternative #3: Car Body Levee Removal)
Increment #35: Upstream LWD Installation	Or (Base Alternative #1: Riverbed Excavation (RM 0-9))
Increment #35: Upstream LWD Installation	Or (Base Alternative #5: Riverbed Excavation (RM 3.5-9)
Increment #35: Upstream LWD Installation	Or (Base Alternative #2: Confluence Channel Excavation)
Increment #37: Grange Levee Setback	(Base Alternative #2: Confluence Channel Excavation)
Increment #37: Grange Levee Setback	Or (Base Alternative #3: Car Body Levee Removal)
Increment #37: Grange Levee Setback	Or (Base Alternative #1: Riverbed Excavation (RM 0-9))
Increment #37: Grange Levee Setback	Or (Base Alternative #5: Riverbed Excavation (RM 3.5-9)
Increment #39: Hunter Creek Tributary Mouth	(Base Alternative #2: Confluence Channel Excavation)
Increment #39: Hunter Creek Tributary Mouth	Or (Base Alternative #3: Car Body Levee Removal)
Increment #40: Hunter Creek Tributary Restoration	(Base Alternative #2: Confluence Channel Excavation And Increment #39:
Increment #40: Hunter Creek Tributary Restoration	Or (Base Alternative #3: Car Body Levee Removal And Increment #39: Hunte
Increment #40: Hunter Creek Tributary Restoration	Or (Base Alternative #5: Riverbed Excavation (RM 3.5-9)
Increment #40: Hunter Creek Tributary Restoration	Or (Base Alternative #1: Riverbed Excavation (RM 0-9))
Increment #43: Weaver Creek Tributary Restoration	(Base Alternative #5: Riverbed Excavation (RM 3.5-9)
Increment #43: Weaver Creek Tributary Restoration	Or (Base Alternative #2: Confluence Channel Excavation)
Increment #43: Weaver Creek Tributary Restoration	Or (Base Alternative #3: Car Body Levee Removal)
Increment #43: Weaver Creek Tributary Restoration	Or (Base Alternative #1: Riverbed Excavation (RM 0-9))
Increment #9: Side Channel Reconnection	(Base Alternative #1: Riverbed Excavation (RM 0-9))
Increment #9: Side Channel Reconnection	Or (Base Alternative #3: Car Body Levee Removal)
Increment #9: Side Channel Reconnection	Or (Base Alternative #2: Confluence Channel Excavation)
Increment #9: Side Channel Reconnection	Or (Base Alternative #5: Riverbed Excavation (RM 3.5-9)
Base Alternative #1: Riverbed Excavation (RM 0-9)	

6. Cost Effectiveness and Incremental Cost Analysis (CE/ICA) Alternatives Evaluation

Traditional benefit-cost analysis is not possible for this restoration study because costs and benefits are expressed in different units. Rather, cost effectiveness and incremental cost analysis (CE/ICA) was used to assist the process of determining what project features and design alternatives should be built based on comparison of quantified habitat benefits (outputs) and estimated costs of alternative feature designs. Cost effectiveness analysis is conducted to ensure that the least cost plan is identified for each possible level of environmental output; and that for any level of investment, the maximum level of output is identified. Subsequent incremental cost analysis of the cost effective plans is conducted to reveal changes in costs as output levels are increased.

Given the IWR Planning Suite inputs described in Section 5, a total of 705 plans were generated. Of these, 60 plans (including the No-Action Alternative) were identified as being cost effective using the cost effectiveness analysis. Cost effective plans are listed in Table 6-1 and all possible plans are displayed in Figure 6-1 as those plans which provide a given level of output at the lowest cost denoted by blue triangles and red squares. Those plans which are not cost effective are denoted by circles. Table 6-1 shows “best buy” plans in bold font, and plans that were carried forward into the final array of alternatives are highlighted in different colors. The process used to carry these plans forward is described in Section 7.

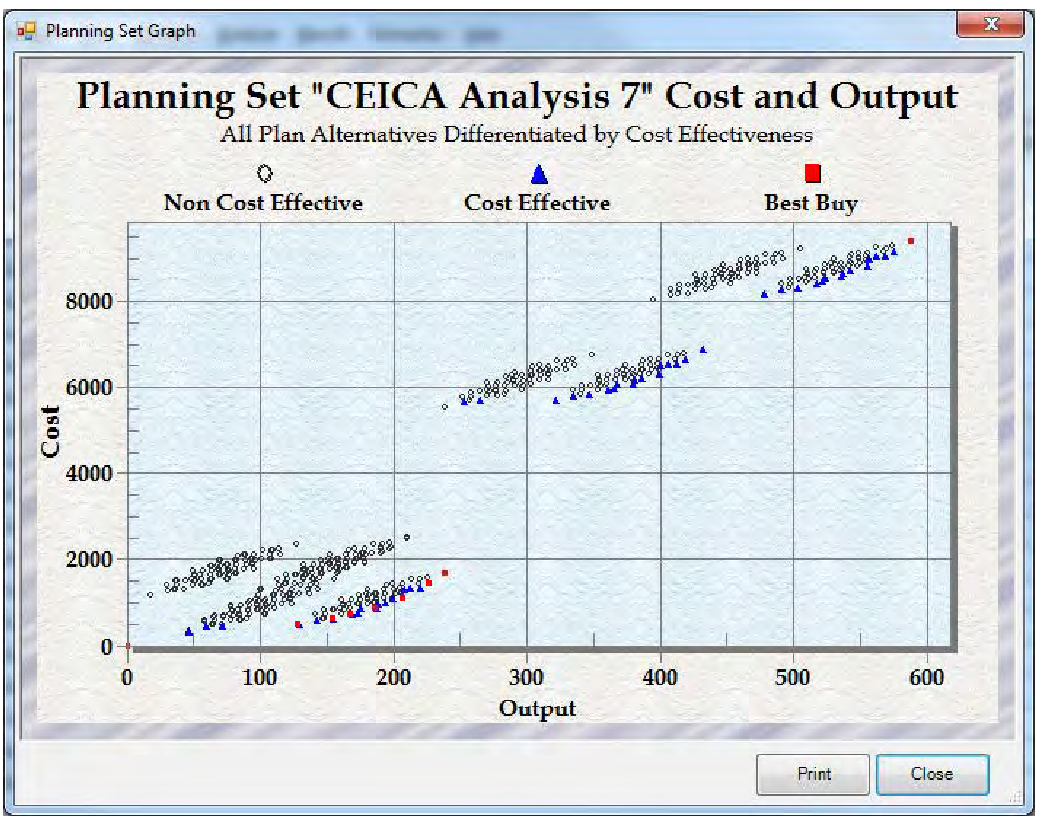


Figure 6-1. Plot of Plan Costs and Output

Table 6-1. Cost Effective Plans*

Alternative # (Original #)	Plan Components	AAHU (In-Channel, Floodplain, and Capacity)	AAHU (Shellfish Substrate)	Total AAHU	Total Average Annual Cost ($1,000s)	Average Annual Cost/ AAHU
1	**No Action Plan**	**0.0**	**0.0**	**0.0**	**0**	
2	Base 3	45.9	0.0	45.9	335	7.30
3	Base 3+ Increment 39	46.2	0.0	46.2	344	7.45
4	Base 3+ Increment 28	59.5	0.0	59.5	440	7.39
5	Base 3+ Increments 28+39	59.8	0.0	59.8	449	7.51
6	Base 3+ Increment 9	71.6	0.0	71.6	473	6.61
7	**Base 3+ Increment 35**	**128.8**	**0.0**	**128.8**	**479**	**3.72**
8	Base 3+ Increments 35+39	129.1	0.0	129.1	488	3.78
9	Base 3+ Increments 35+28	142.4	0.0	142.4	584	4.10
10	Base 3+ Increments 35+28+39	142.7	0.0	142.7	593	4.16
11	**Base 3+ Increments 35+9**	**154.5**	**0.0**	**154.5**	**617**	**3.99**
12	Base 3+ Increments 35+9+39	154.8	0.0	154.8	626	4.04
13	**Base 3+ Increments 35+9+28**	**168.1**	**0.0**	**168.1**	**722**	**4.30**
14	Base 3+ Increments 35+9+28+39	168.4	0.0	168.4	731	4.34
15	Base 3+ Increments 35+9+37	173.0	0.0	173.0	763	4.41
16	Base 3+ Increments 35+9+37+39	173.3	0.0	173.3	772	4.45
17	Base 3+ Increments 35+9+39+40	174.9	0.0	174.9	862	4.93
18	**Base 3+ Increments 35+9+28+37**	**186.6**	**0.0**	**186.6**	**868**	**4.65**
19	Base 3+ Increments 35+9+28+37+39	186.9	0.0	186.9	877	4.69
20	Base 3+ Increments 35+9+39+40+28	188.5	0.0	188.5	967	5.13
21	Base 3+ Increments 35+9+37+39+40	193.4	0.0	193.4	1,008	5.21
22	Base 3+ Increments 35+9+28+37+26	199.3	0.0	199.3	1,104	5.54
23	**Base 3+ Increments 35+9+28+37+39+40**	**207.0**	**0.0**	**207.0**	**1,113**	**5.38**
24	Base 3+ Increments 35+9+28+39+40+43	207.9	0.0	207.9	1,306	6.28
25	Base 3+ Increments 35+9+37+39+40+43	212.8	0.0	212.8	1,347	6.33
26	Base 3+ Increments 35+9+28+37+39+40+26	219.7	0.0	219.7	1,349	6.14
27	**Base 3+ Increments 35+9+37+39+40+43+28**	**226.4**	**0.0**	**226.4**	**1,452**	**6.41**
28	**Base 3+ Increments 35+9+37+39+40+43+28+26**	**239.1**	**0.0**	**239.1**	**1,688**	**7.06**
29	Base 5+ Increment 28	124.6	127.8	252.4	5,653	22.40
30	Base 5+ Increment 9	136.7	127.8	264.5	5,686	21.50
31	Base 5+ Increment 35	193.9	127.8	321.7	5,692	17.69
32	Base 5+ Increments 35+28	207.5	127.8	335.3	5,797	17.29
33	Base 5+ Increments 35+9	219.6	127.8	347.4	5,830	16.78
34	Base 5+ Increments 35+9+28	233.2	127.8	361.0	5,935	16.44
35	Base 5+ Increments 35+9+37	238.1	127.8	365.9	5,976	16.33
36	Base 5+ Increments 35+9+40	239.7	127.8	367.5	6,066	16.51
37	Base 5+ Increments 35+9+28+37	251.7	127.8	379.5	6,081	16.02
38	Base 5+ Increments 35+9+28+40	253.3	127.8	381.1	6,171	16.19
39	Base 5+ Increments 35+9+40+37	258.2	127.8	386.0	6,212	16.09
40	Base 5+ Increments 35+9+40+37+28	271.8	127.8	399.6	6,317	15.81
41	Base 5+ Increments 35+9+28+40+43	272.7	127.8	400.5	6,510	16.25
42	Base 5+ Increments 35+9+28+40+43+37	277.6	127.8	405.4	6,551	16.16
43	Base 5+ Increments 35+9+40+37+28+26	284.5	127.8	412.3	6,553	15.89
44	Base 5+ Increments 35+9+40+37+28+43	291.2	127.8	419.0	6,656	15.89
45	Base 5+ Increments 35+9+40+37+28+43+26	303.9	127.8	431.7	6,892	15.96

Alternative # (Original #)	Plan Components	AAHU (In-Channel, Floodplain, and Capacity)	AAHU (Shellfish Substrate)	Total AAHU	Total Average Annual Cost ($1,000s)	Average Annual Cost/ AAHU
46	Base 1+ Increment 35	267.1	210.8	477.9	8,179	17.11
47	Base 1+ Increments 35+28	280.7	210.8	491.5	8,284	16.85
48	Base 1+ Increments 35+9	292.8	210.8	503.6	8,317	16.52
49	Base 1+ Increments 35+9+28	306.4	210.8	517.2	8,422	16.28
50	Base 1+ Increments 35+9+37	311.3	210.8	522.1	8,463	16.21
51	Base 1+ Increments 35+9+40	312.9	210.8	523.7	8,553	16.33
52	Base 1+ Increments 35+9+28+37	324.9	210.8	535.7	8,568	15.99
53	Base 1+ Increments 35+9+28+40	326.5	210.8	537.3	8,658	16.11
54	Base 1+ Increments 35+9+40+37	331.4	210.8	542.2	8,699	16.04
55	Base 1+ Increments 35+9+40+37+28	345.0	210.8	555.8	8,804	15.84
56	Base 1+ Increments 35+9+28+40+43	345.9	210.8	556.7	8,997	16.16
57	Base 1+ Increments 35+9+28+40+43+37	350.8	210.8	561.6	9,038	16.09
58	Base 1+ Increments 35+9+40+37+28+26	357.7	210.8	568.5	9,040	15.90
59	Base 1+ Increments 35+9+40+37+28+43	364.4	210.8	575.2	9,143	15.90
60	**Base 1+ Increments 35+9+40+37+28+43+26**	**377.1**	**210.8**	**587.9**	**9,379**	**15.95**

*Plans in bold represent "Best Buy" plans.

Incremental cost analysis identified nine of the cost effective plans as "Best Buy" plans, defined as those cost effective plans which provide the greatest incremental increase in output (benefits) for the lowest incremental increase in cost. These best buy plans are listed in Table 6-2 and include total output, total average annual cost, average cost per output, and incremental cost per incremental output. The incremental costs of the best buy plans are displayed as a bar graph in Figure 6-2. The first best buy plan is the No Action Plan. Seven of the remaining eight best buy plans are combinations of increments with Base #3 Car Body Levee Removal. The last best buy (Plan #60/Best Buy 9) is Base #1 Riverbed Excavation RM 0-9 with all combinable increments. The incremental cost per output of the last best buy is $22K per AAHU, or an approximate $3.5K incremental cost per unit than the previous best buy (Plan #28/Best Buy 8). The study team included a smaller scale sediment excavation plan (Base #5 Riverbed Excavation RM 3.5-9) in the final array of alternatives due to the high cost and scale of Base #1 Riverbed Excavation RM 0-9. The Base #5 plan carried forward is Plan #45 from the cost effective plans. The incremental cost per output for this plan is estimated at $27K per AAHU, which has a higher incremental cost per output than the large scale riverbed excavation plan (Plan #60/Best Buy 9).

Table 6-2. Best Buy Plans and Increment Cost per Incremental Output

Alternative #	Plan Components	Total Output in AAHU's	Total Average Annual Cost (AAC in $K)	AAC/ AAHU ($K)	Incremental Cost/Incremental Output ($K)	Total Present Value Cost ($K)	Cost Effective and/or Best Buy?	Improves Egg-to-Fry Survival?
1	No Action Plan	0.0	0				Best Buy 1	No
7	Base #3: Car Body Levee Removal +35	128.8	479	$3.71	$3.71	$10,754	Best Buy 2	No
11	Base #3: Car Body Levee Removal +35+9	154.5	617	$3.99	$5.37	$13,850	Best Buy 3	No
13	Base #3: Car Body Levee Removal +35+9+28	168.1	722	$4.30	$7.72	$16,215	Best Buy 4	No
18	Base #3: Car Body Levee Removal +35+9+28+37	186.6	868	$4.65	$7.89	$19,492	Best Buy 5	No
23	Base #3: Car Body Levee Removal +35+9+28+37+39+40	207.0	1,113	$5.38	$12.01	$24,999	Best Buy 6	No
27	Base #3: Car Body Levee Removal +35+9+37+28+39+40+43	226.4	1,452	$6.41	$17.47	$32,602	Best Buy 7	No
28	Base #3: Car Body Levee Removal +35+9+37+28+39+40+43+26	239.1	1,688	$7.06	$18.58	$37,887	Best Buy 8	No
45	Base #5: Riverbed Excavation RM 3.5-9 +35+9+37+28+40+43+26	431.7	6,892	$15.96	$27.02	$154,623	Cost Effective	Yes
60	Base #1: Riverbed Excavation RM 0-9 +35+9+37+28+40+43+26	587.9	9,379	$16.00	$22.05	$210,434	Best Buy 9	Yes

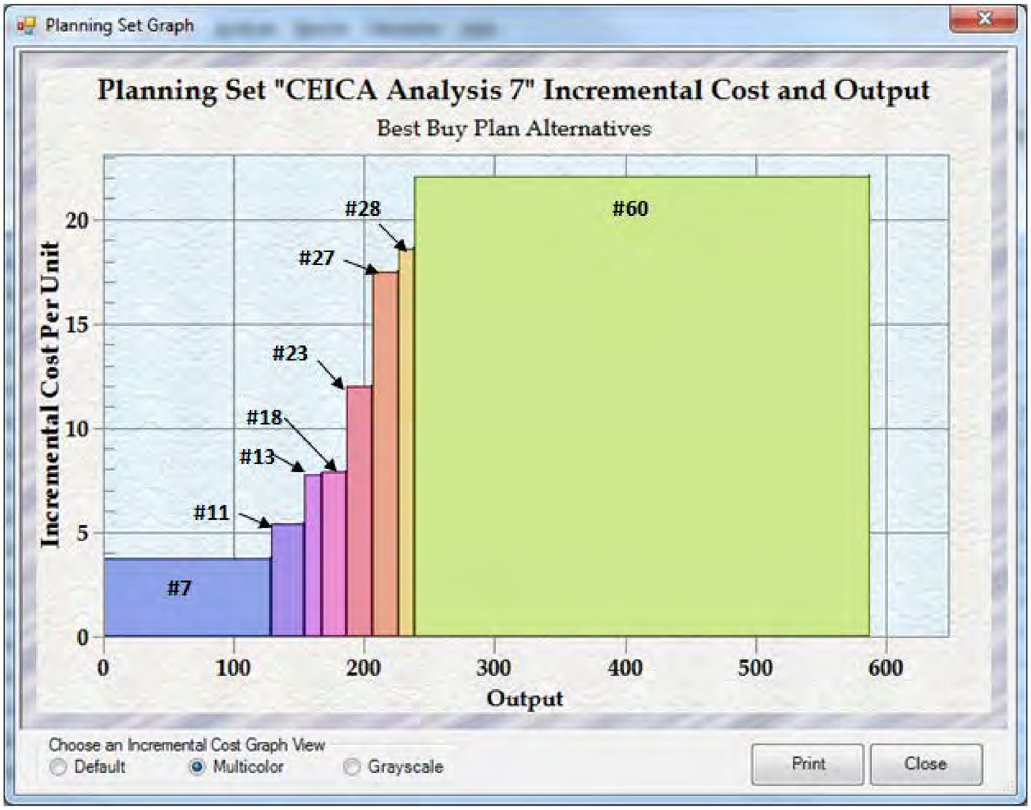


Figure 6-2. Incremental Cost and Output

7. Final Array of Alternatives

The alternatives carried forward for detailed evaluation in the final array were chosen based on CE/ICA results, total cost, incremental cost, and ecological value added between increments. This step resulted in carrying forward six alternatives (including the No Action Alternative) into the final array of alternatives. Alternative #7 was carried forward because it is the least cost best buy; this plan represents the minimum Federal investment for the study. Alternative #23 was carried forward because it is the first alternative that includes tributary restorations, a critical measure that restores spawning and rearing habitats in the floodplain. While Alternative #18 has a minimal increase in incremental cost for additional HUs, it was not carried forward because it does not include tributary restorations. Alternative #28 was carried forward because it represents the largest-scale Car Body Levee Removal alternative. While Alternative #45 is cost effective only, it was carried forward into the final array of alternatives because it meets the critical needs of the study area while requiring a smaller extent of dredging compared to Alternative #60. Alternative #60 was carried forward because it is the largest-scale Best Buy Plan and represents the most significant Federal investment for the study.

The best buy plans carried forward into the final array of alternatives is shown in Figure 7-1. Descriptions of the final array of alternatives are included in the draft feasibility report.

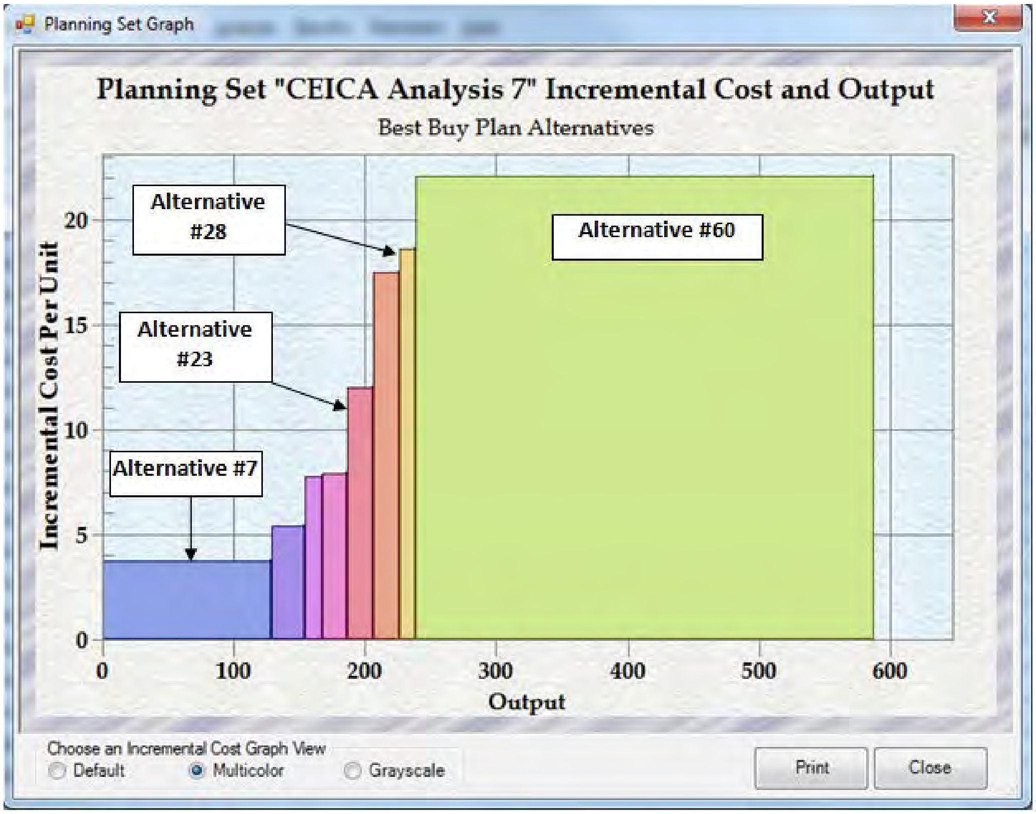


Figure 7-1. Best Buy Plans Carried Forward into Final Array of Alternatives

Table 7-3 summarizes the habitat benefit (AAHU's), acres restored, and average annual cost of the final array of alternatives. The total AAHU's and average annual cost of the alternatives are plotted in Figure 7-2. A plot of the incremental cost per output which includes cost effective Alternative #45 is shown in Figure 7-3. Alternative #45 is approximately $5,000 per incremental output greater than Alternative #60.

Table 7-1. Habitat Outputs and Costs of Final Array of Alternatives

Alternative #	Plan Components	Habitat Units (In-Channel, Floodplain, and Capacity)	Habitat Units (Shellfish Substrate)	Total Habitat Units	Total Acres Restored	Total Annual Cost ($1,000s)
No Action Alternative						
1	No Action Plan	0	n/a	0	0	$0
Car Body Levee Removal Alternatives						
7	Alternative #7 Car Body Levee Removal Scale: *Base #3: Car Body Levee Removal* *Increment 35 – Upstream LWD*	128.8	n/a	128.8	175 In-Channel and Floodplain	$479
23	Alternative #23 Car Body Levee Removal: Base #3: Car Body Levee Removal Increment 35 – Upstream LWD *Increment 9 – Side Channel Restoration* *Increment 37 – Grange Levee Setback* *Increment 28 – River Mile 9 Levee Setback* *Increment 39 – Hunter Creek Tributary Mouth* *Increment 40 – Hunter Creek Tributary Restoration*	207.0	n/a	207.0	306.5 In-Channel and Floodplain	$1,113
28	Alternative #28: Car Body Levee Removal: Base #3: Car Body Levee Removal Increment 35 – Upstream LWD Increment 9 – Side Channel Restoration Increment 37 – Grange Levee Setback Increment 28 – River Mile 9 Levee Setback Increment 39 – Hunter Creek Tributary Mouth Increment 40 – Hunter Creek Tributary Restoration *Increment 43 – Weaver Creek Tributary Restoration* *Increment 26 – Dips Road Setback*	239.1	n/a	239.1	348.5 In-Channel and Floodplain	$1,688
Riverbed Excavation Alternatives						
45	Alternative #45 Riverbed Excavation: *Base #5: Riverbed Excavation (RM 3.5-9)* Increment 35 – Upstream LWD Increment 9 – Side Channel Restoration Increment 37 – Grange Levee Setback Increment 28 – River Mile 9 Levee Setback Increment 40 – Hunter Creek Tributary Restoration Increment 43 – Weaver Creek Tributary Restoration Increment 26 – Dips Road Setback	303.9	127.8	431.7	412 In-Channel & Floodplain + 511 Shellfish = 923 Total Acres Restored	$6,892

Alternative #	Plan Components	Habitat Units (In-Channel, Floodplain, and Capacity)	Habitat Units (Shellfish Substrate)	Total Habitat Units	Total Acres Restored	Total Annual Cost ($1,000s)
60	Alternative #60 Riverbed Excavation: *Base #1: Riverbed Excavation (RM 0-9)* Increment 35 – Upstream LWD Increment 9 – Side Channel Restoration Increment 37 – Grange Levee Setback Increment 28 – River Mile 9 Levee Setback Increment 40 – Hunter Creek Tributary Restoration Increment 43 – Weaver Creek Tributary Restoration Increment 26 – Dips Road Setback	377.1	210.8	587.9	499 In-Channel & Floodplain + 843 Shellfish = 1,342 Total Acres Restored	$9,379

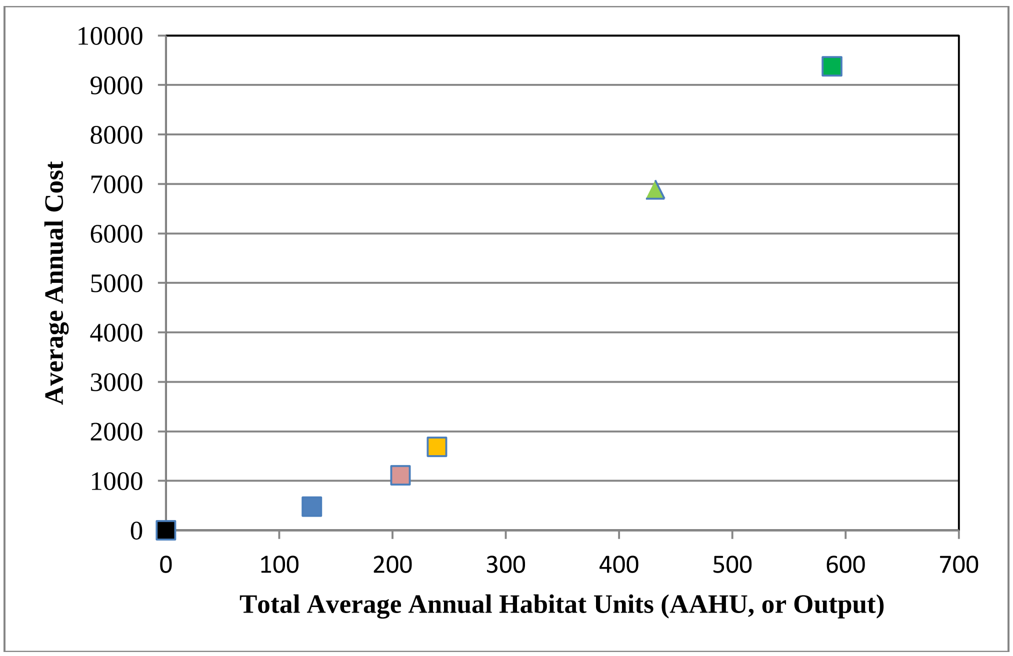


Figure 7-2. Outputs and Costs of Final Array of Alternatives Plot*

*Square denotes “Best Buy” plan; triangle denotes “Cost Effective” plan

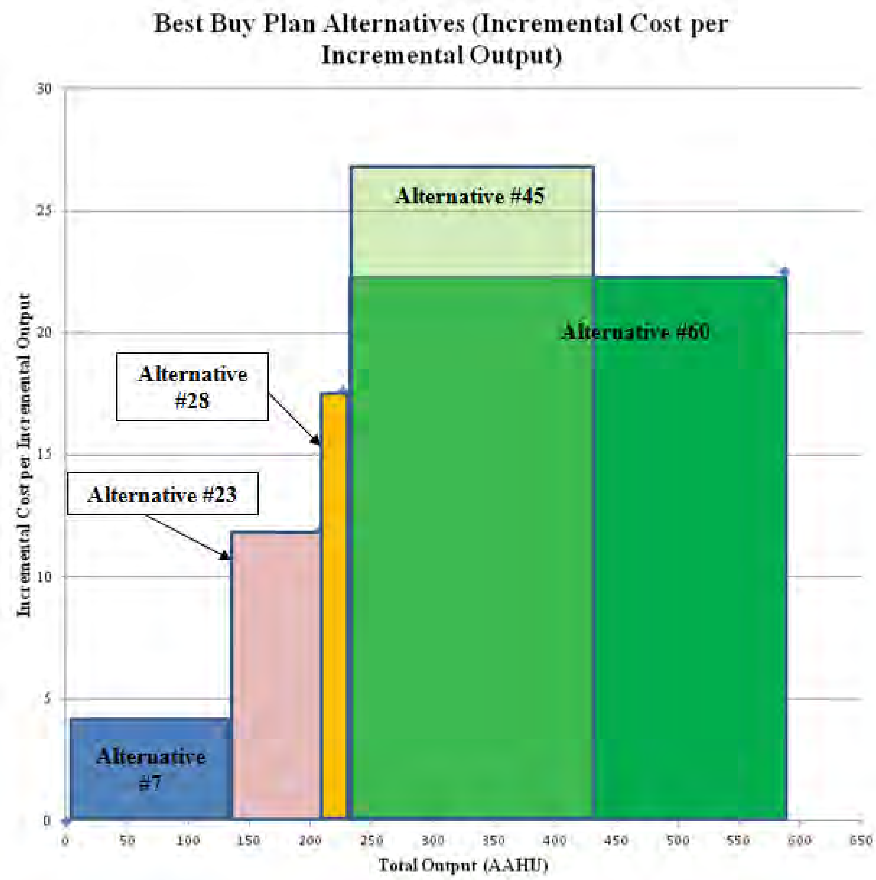


Figure 7-3. Incremental Costs for Final Array of Alternatives

8. Sensitivity Analysis

8.1 CE/ICA With EO Model Outputs Only

A sensitivity run of the cost effectiveness and incremental analysis was performed on the EO Model outputs only, with benefits for shellfish substrate not included in this model. Costs for the base alternatives and increments did not change. Outputs for Bases #1 and #5 were reduced from 395.0 and 238.8 to 184.2 and 111.0, respectively. Figure 8-1 shows a plot of costs and outputs for each possible plan combination. There were 705 possible plan combinations, 50 of which were cost effective plans, and 9 of which were best buy plans. The best buy plans for this run of incremental cost analysis were the same as the best buy plans identified from the incremental cost analysis that included the shellfish benefits. Incremental costs for Best Buy 9 (Base #1 with each combinable increment) increased from $22.05 to $55.73 per incremental output. The best buy incremental costs are displayed in Figure 8-2, and the incremental costs of the best buy plans are included in Table 8-1. The final array of alternatives is highlighted in Table 8-1. Without inclusion of the shellfish substrate benefits, total AAHU's are reduced from 587.9 to 377.1 which results in a steeper and narrower bar for the last best buy plan (Best Buy 9, green bar) as the bar graph shown in Figure 6-2.

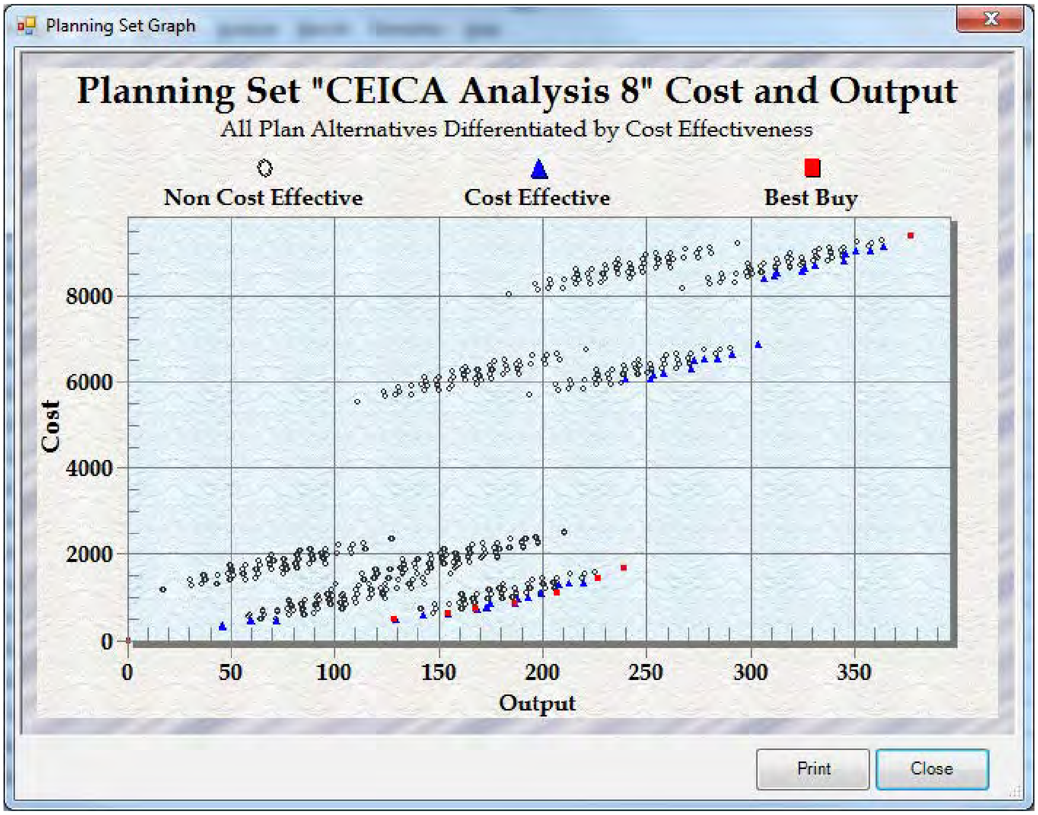


Figure 8-1. Plot of Plan Costs and Outputs, EO Model Benefits Only

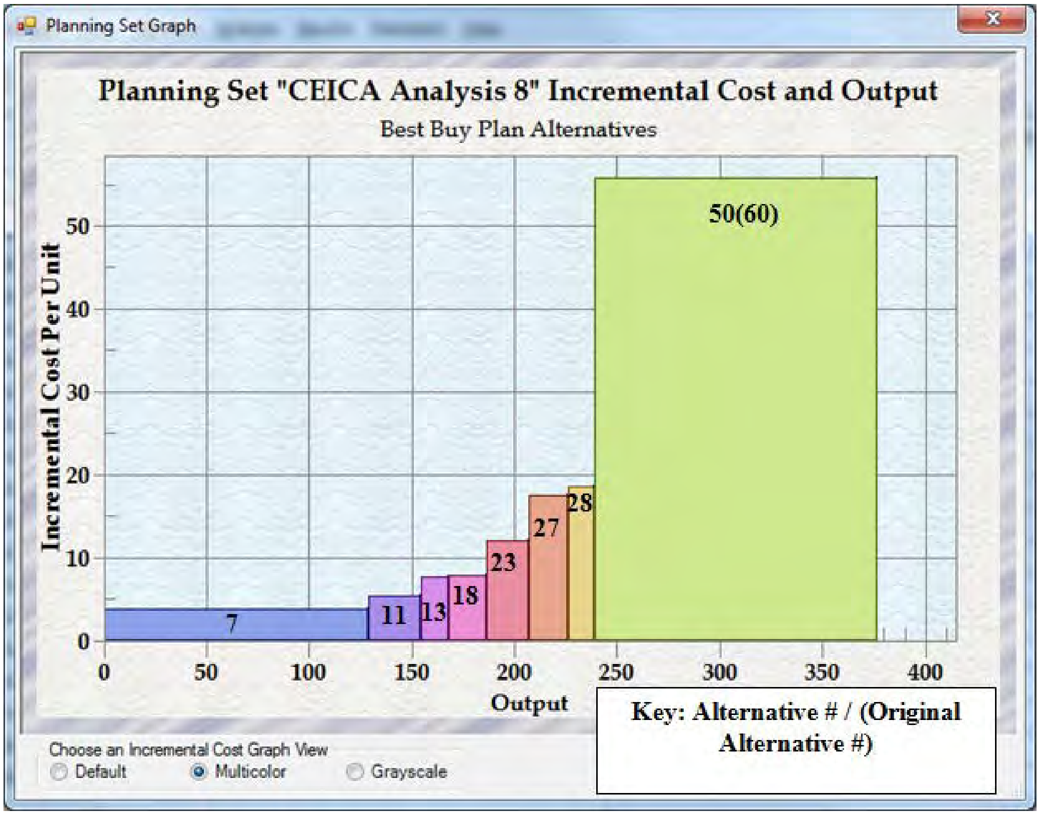


Figure 8-2. Incremental Cost and Output, EO Model Benefits Only

Table 8-1. Best Buy Plans, EO Model Benefits Only

Alternative # (Original Alternative #)	Plan Components	Total Output in AAHU's (EO Model)	Total Average Annual Cost (AAC in $K)	AAC/ AAHU ($K)	Incremental Cost/Incremental Output ($K)	Total Present Value Cost ($K)	Cost Effective and/or Best Buy?	Improves Egg-to-Fry Survival?
1	No Action Plan	0.0	0				Best Buy	No
7	Base #3: Car Body Levee Removal +35	128.8	479	$3.72	$3.72	$10,754	Best Buy	No
11	Base e #3: Car Body Levee Removal +35+9	154.5	617	$3.99	$5.37	$13,850	Best Buy	No
13	Base #3: Car Body Levee Removal +35+9+28	168.1	722	$4.30	$7.72	$16,215	Best Buy	No
18	Base #3: Car Body Levee Removal +35+9+28+37	186.6	868	$4.65	$7.89	$19,492	Best Buy	No
23	Base #3: Car Body Levee Removal +35+9+28+37+39+40	207.0	1,113	$5.38	$12.01	$24,999	Best Buy	No
27	Base #3: Car Body Levee Removal +35+9+37+28+39+40+43	226.4	1,452	$6.41	$17.47	$32,602	Best Buy	No

Alternative # (Original Alternative #)	Plan Components	Total Output in AAHU's (EO Model)	Total Average Annual Cost (AAC in $K)	AAC/ AAHU ($K)	Incremental Cost/Incremental Output ($K)	Total Present Value Cost ($K)	Cost Effective and/or Best Buy?	Improves Egg-to-Fry Survival?
28	Base #3: Car Body Levee Removal +35+9+37+28+39+40+43+26	239.1	1,688	$7.06	$18.58	$37,887	Best Buy	No
38(45)	Base #5: Riverbed Excavation RM 3.5-9 +35+9+37+28+40+43+26	303.9	6,892	$22.68	$71.09	$154,623	Cost Effective	Yes
50(60)	Base #1: Riverbed Excavation RM 0-9 +35+9+37+28+40+43+26	377.1	9,379	$24.87	$55.73	$210,434	Best Buy	Yes

8.2 CE/ICA without Increment #26 – Dips Road

A sensitivity run of the cost effectiveness and incremental analysis was performed with removal of Increment #26, Dips Road. Figure 8-3 shows a plot of costs and outputs for each possible plan combination. There were 321 possible plan combinations, 55 of which were cost effective plans, and 8 of which were best buy plans. The best buy plans for this run of incremental cost analysis were slightly different than the best buy plans identified from the incremental cost analysis that included Increment #26, with removal of Plan #28, or the best buy plan for Base #3 which included all increments. The last best buy plan for Base #3 is now Plan #27, which does not include Increment #26. The best buy which includes Base 1 and the cost effective plan which includes Base 5 did not include benefits and costs for Increment #26. Outputs for Bases #1 and #5 were reduced from 587.9 and 431.7 to 575.2 and 419, respectively. Incremental costs for the Base #1 best buy (original Plan #59, now Plan #55) and Base #5 cost effective plan (original Plan #44, now Plan #41) did not change from the evaluation presented in Chapter 6. The best buy incremental costs are displayed in Figure 8-4, and the incremental costs of the best buy plans are included in Table 8-2.

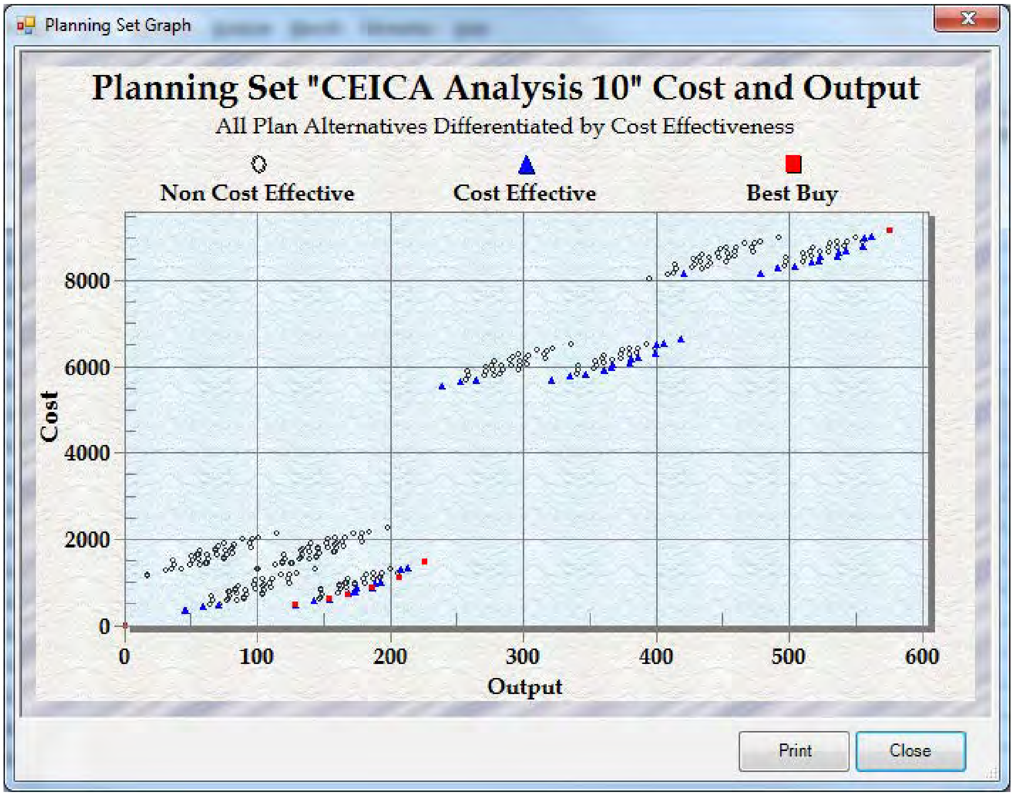


Figure 8-3. Plot of Plan Costs and Outputs, Without Increment #26 – Dips Road

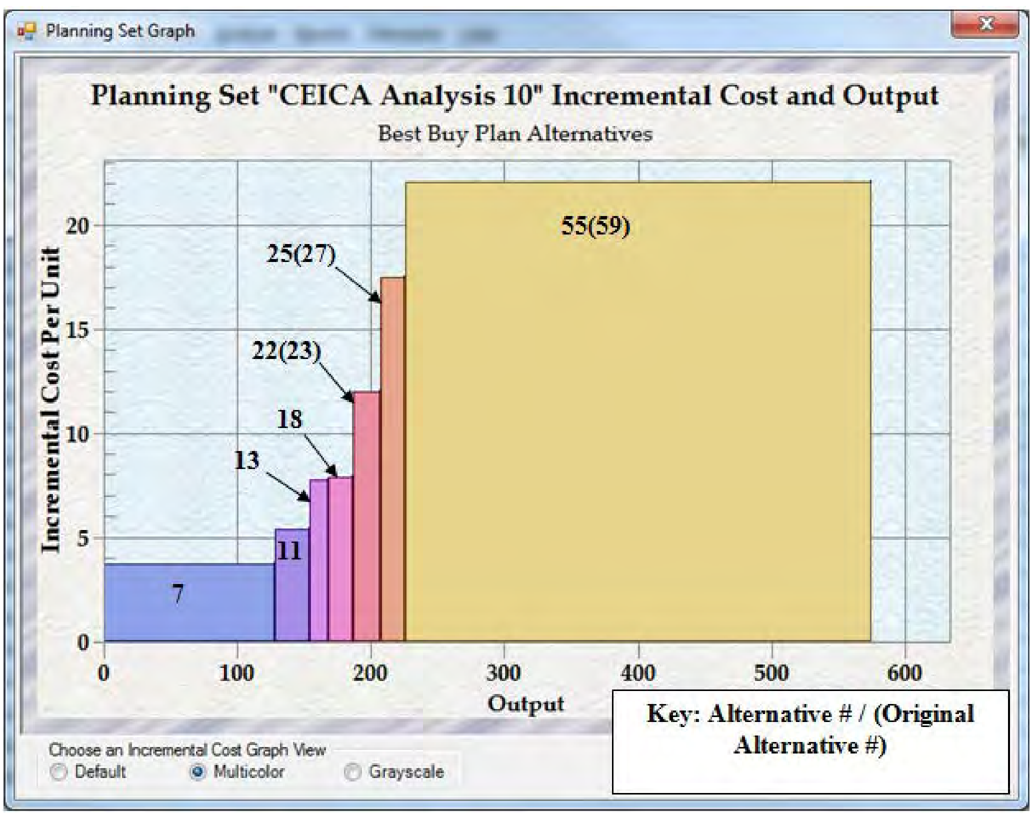


Figure 8-4. Incremental Cost and Output, Without Increment #26 – Dips Road

Table 8-2. Best Buy Plans, Without Increment #26 – Dips Road

Alternative # (Original Alternative #)	Plan Components	Total Output in AAHU's (EO Model)	Total Average Annual Cost (AAC in $K)	AAC/ AAHU ($K)	Incremental Cost/Incremental Output ($K)	Total Present Value Cost ($K)	Cost Effective and/or Best Buy?	Improves Egg-to-Fry Survival?
1	No Action Plan	0.0	0				Best Buy	No
7	Base #3: Car Body Levee Removal +35	128.8	479	$3.72	$3.72	$10,754	Best Buy	No
11	Base #3: Car Body Levee Removal +35+9	154.5	617	$3.99	$5.37	$13,850	Best Buy	No
13	Base #3: Car Body Levee Removal +35+9+28	168.1	722	$4.30	$7.72	$16,215	Best Buy	No
18	Base #3: Car Body Levee Removal +35+9+28+37	186.6	868	$4.65	$7.89	$19,492	Best Buy	No
22(23)	Base #3: Car Body Levee Removal +35+9+28+37+39+40	207.0	1,113	$5.38	$12.01	$24,999	Best Buy	No
25(27)	Base #3: Car Body Levee Removal +35+9+37+28+39+40+43 +26	226.4	1,452	$6.41	$17.47	$32,602	Best Buy	No
41(44)	Base #5: Riverbed Excavation RM 3.5-9 +35+9+37+28+40+43+26	419.0	6,656	$15.89	$27.02	$154,623	Cost Effective	Yes
55(59)	Base #1: Riverbed Excavation RM 0-9 +35+9+37+28+40+43+26	575.2	9,143	$15.90	$22.05	$210,434	Best Buy	Yes

9. Tentatively Selected Plan (TSP)

Alternative 27, Car Body Levee Removal, is the tentatively selected plan (TSP) and the NER plan. The TSP is both cost effective and a best buy plan (Plan #27/Best Buy #7). The draft feasibility report describes the evaluation and comparison of alternatives, as well as the direct, indirect, and cumulative environmental impacts or consequences of each alternative including the TSP.

The annual costs and benefits of the TSP components are shown in Table 9-1based on conceptual costs developed for the cost effectiveness and incremental cost analyses. The TSP results in 331.5 acres of restoration with 226.4 average annual habitat units (AAHU's) with in-channel and floodplain benefits distributed throughout the Lower Skokomish Watershed.

Table 9-1. Tentatively Selected Plan Components

Alternative #	Plan Components	Habitat Units (In-Channel, Floodplain, and Capacity)	Habitat Units (Shellfish Substrate)	Total Habitat Units	Total Acres Restored	Total Annual Cost ($1,000s)
27	Alternative 2A Car Body Levee Removal:					
	Base #3: Car Body Levee Removal	45.9	0	45.9	68	$335
	Increment 35 – Upstream LWD	82.9	0	82.9	107	144
	Increment 9 – Side Channel Restoration	25.7	0	25.7	45	138
	Increment 37 – Grange Levee Setback	18.5	0	18.5	34	146
	Increment 28 – River Mile 9 Levee Setback	13.6	0	13.6	23	105
	Increment 39 – Hunter Creek Tributary Mouth	0.5	0	0.5	0.5	9
	Increment 40 – Hunter Creek Tributary Restoration	20.1	0	20.1	29	236
	Increment 43 – Weaver Creek Tributary Restoration	19.4	0	19.4	25	339
	Totals for Tentatively Selected Plan	**226.4**	**0**	**2264**	**331.5**	**$1,462**

Project costs underwent a cost and schedule risk analysis to develop contingencies for the alternatives considered. Table 9-2 summarizes the refined project first costs (constant dollar basis at the October 2015 price level) and the fully funded cost estimate to midpoint of construction for the TSP. The project first cost is estimated at $40,753,000 and the fully funded cost estimate is estimated at $41,746,000.

Table 9-2. Tentatively Selected Plan Cost Estimate

Cost Feature	Project First Cost (Constant Dollar Basis, Program Year 2016, $1,000s)	Total Project Cost (Fully Funded, $1,000s)
06 Fish & Wildlife Facilities	$1,083	$1,102
09 Channels & Canals	16,124	16,460
11 Levees & Floodwalls	5,235	5,328
Subtotal Construction Cost	***$22,442***	***$22,891***
01 Lands & Damages (LERRD)	7,574	7,710
30 Planning, Engineering and Design (PED)	6,954	7,217
31 Construction Management	3,784	3,927
Total Construction Costs	**$40,753**	**$41,746**

Table 9-3 provides an economic summary of the TSP. Interest during construction was computed using project first costs, anticipated construction duration, and the current Federal discount rate (3.5% for fiscal year 2014), bringing total investment costs to $41,545,000. Minimal operations and maintenance expenses are expected at this time and have been estimated at $5,000 for the TSP. Annual costs were updated using the current cost estimate. Average annual cost is estimated at $1,776,000, with an average annual cost of $8,000 per AAHU.

Table 9-3. Economic Summary for Tentatively Selected Plan

	Cost and Benefit Summary of TSP
Interest Rate (Fiscal Year 2014)	3.5%
Interest Rate, Monthly	0.29%
Construction Period, Years	2
Period of Analysis, Years	50
Project First Cost	$40,753,000
Interest During Construction	$803,000
Investment Cost	$41,545,000
Average Annual Cost	
Amortized Cost	$1,771,000
OMRR&R	$5,000
Total Annual Cost	$1,776,000
Average Annual Benefits	
Average Annual Habitat Units (AAHUs)	226.4
Average Annual Cost/AAHU	$7,845

Table 9-4 summarizes the cost sharing for the TSP. Lands, easements, right-of-ways, relocations, and disposals (LERRDs) are credited towards the non-Federal sponsor’s 35 percent cost share responsibility. LERRDs in excess of 35% are reimbursed to the sponsor. The Federal and non-Federal shares of the total project first cost estimated at $26,490,000 and $14,264,000, respectively.

Table 9-4. Project Cost Share of Tentatively Selected Plan

	Federal ($1,000s)	Non-Federal ($1,000s)	Total ($1,000s)
Ecosystem Restoration			
Lands & Damages		$7,574	$7,574
Fish & Wildlife Facilities	$1,083		$1,083
Channels & Canals	$16,124		$16,124
Levees & Floodwalls	$5,235		$5,235
Planning, Engineering & Design	$6,954		$6,954
Construction Management	$3,784		$3,784
Cash Contribution/Reimbursement	($5,590)	$6,690	$0
Total Project Cost Share	**$26,490**	**$14,264**	**$40,753**
Total Project Cost Share (%)	**65%**	**35%**	**100%**
Total Project Cost Share (Fully Funded)	**$27,135**	**$14,611**	**$41,746**

10. References

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http://planning.usace.army.mil/toolbox/library/Guidance/Principles_Guidelines.pdf (Accessed 25 September 2013).

SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

APPENDIX H

ENGINEERING

DRAFT Integrated Feasibility Report and Environmental Impact Statement

US Army Corps of Engineers
Seattle District

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TABLE OF CONTENTS

1 CIVIL DESIGN

This section discusses the key elements of the civil design and determines the gross volumes associated with each of feature included in the Focused Array of Alternatives that were used in cost determinations. The discussion includes the major components, construction, access and staging considerations. Further discussion of alternative selection for the Focused and Final Arrays of Alternatives are presented in the plan formulation section of the Draft Feasibility Report/Environmental Impact Statement. We present the Focused Array in the Engineering Appendix to support the cost determinations and the selection of the Final Array.

1.1 NAMING CONVENTIONS

Proposed project features are largely named similarly in the development of the draft feasibility report however, because the project feature names differ slightly throughout the development the table below lists presents some of the naming conventions used in the sections of the draft feasibility report.

Table 1-1. NAMING CONVENTION of BASES

PREVIOUS NAMING	MAIN BODY DRAFT FEASIBILITY REPORT
Alternative 1, Base 1, Base Alternative 1,	Base #1: Riverbed Excavation (RM 0-9)
(Base #3) Car Body Levee, Car Body Degrade	Base #3: Car Body Levee Removal
Alternative 5, Base 5, Base Alternative 5, RM 3.5-9 Dredge (Base #5), Dredge River from Rm 3.5-9	Base #5: Riverbed Excavation (RM 3.5-9)

Table 1-2. NAMING CONVENTION of INCREMENTS

PREVIOUS NAMING	MAIN BODY DRAFT FEASIBILITY REPORT
LWD	Increment #35: Upstream LWD Installation
#9, Side Channel #9, river channel reconnection RM 4-5.6	Increment #9: Side Channel Reconnection
Grange Levee Setback, Grange Levee Degrade	Increment #37: Grange Levee Setback
Large Levee Setback, Large Levee Degrade	Increment #28: River Mile 9 Levee Setback
Hunter Creek	Increment #40: Hunter Creek Tributary Restoration
Weaver Creek	Increment #43: Weaver Creek Tributary Restoration
Dips Road Relocation, Dips Road Degrade	Increment #26: Dips Road Setback

1.2 SITE SELECTION AND PROJECT DEVELOPMENT

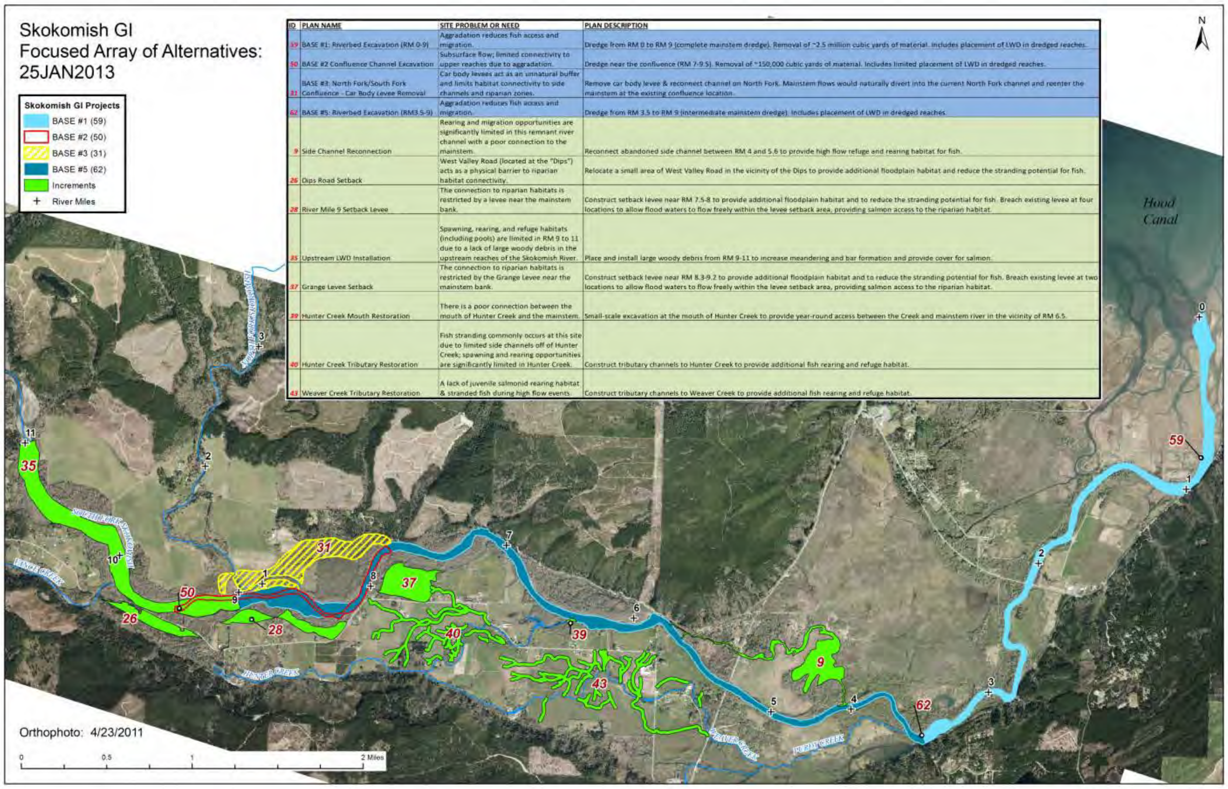
To guide alternatives formulation, the study team identified the planning objectives of the study. Based on the problems identified in the study area, planning objectives include the following:

- Provide year-round passage for fish species around the confluence of the North Fork and South Fork Skokomish River for the 50-year period of analysis.
- Reconnect and restore the spawning, rearing, and refuge habitats in the study's side channel and tributary networks including Hunter and Weaver Creeks for the 50-year period of analysis.
- Improve the quantity, quality, and complexity of native riparian and floodplain habitats in the study area for the 50-year period of analysis.

- Improve the quantity, quality, and complexity of pools in the Skokomish River to promote spawning and rearing success, as well as reduce stranding of ESA-listed salmonid species for the 50-year period of analysis.

The map below presents the Focused Array of alternatives. This map is also presented in larger format for improved readability in the annex to the engineering appendix below.

Figure 1. Focused Array of Alternatives

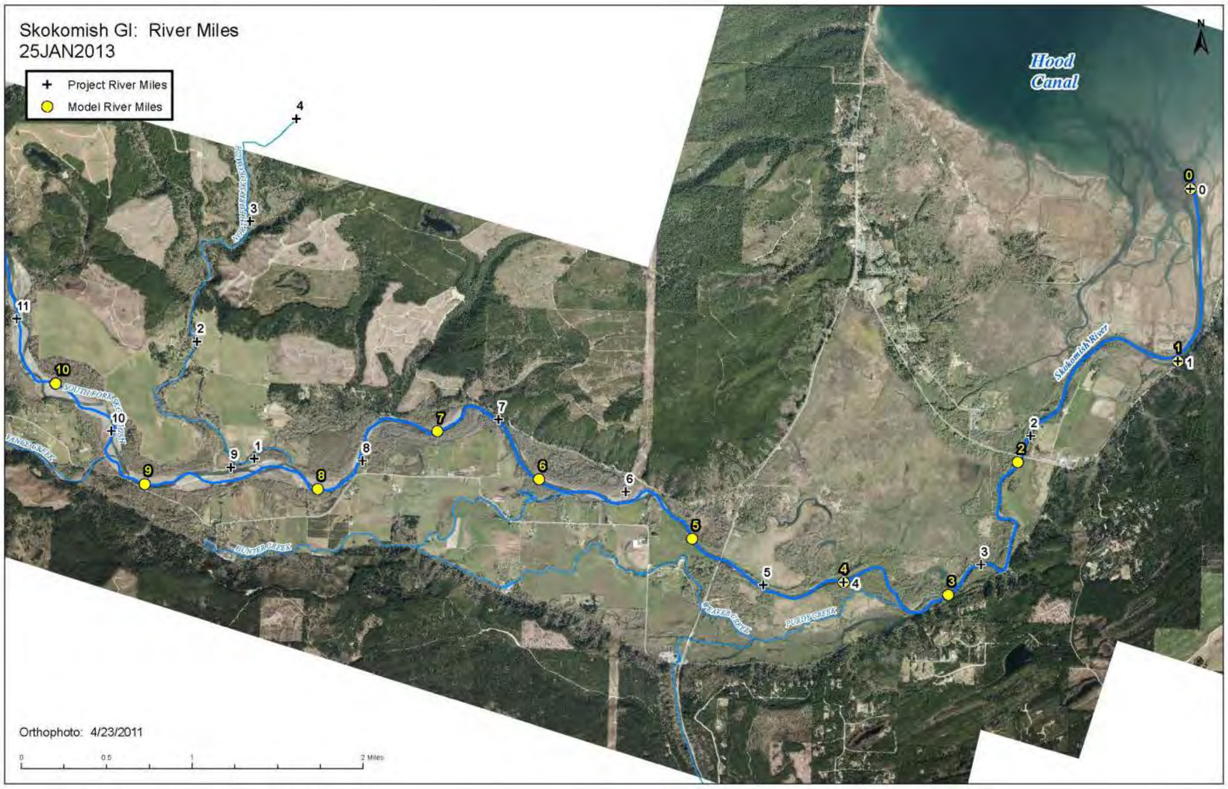


ID	PLAN NAME	SITE PROBLEM OR NEED	PLAN DESCRIPTION
59	BASE #1: Riverbed Excavation (RM 0-9)	Aggradation reduces fish access and migration.	Dredge from RM 0 to RM 9 (complete mainstem dredge). Removal of ~2.5 million cubic yards of material. Includes placement of LWD in dredged reaches.
50	BASE #2 Confluence Channel Excavation	Subsurface flow; limited connectivity to upper reaches due to aggradation.	Dredge near the confluence (RM 7-9.5). Removal of ~150,000 cubic yards of material. Includes limited placement of LWD in dredged reaches.
31	BASE #3: North Fork/South Fork Confluence - Car Body Levee Removal	Car body levees act as an unnatural buffer and limits habitat connectivity to side channels and riparian zones.	Remove car body levee & reconnect channel on North Fork. Mainstem flows would naturally divert into the current North Fork channel and reenter the mainstem at the existing confluence location.
62	BASE #5: Riverbed Excavation (RM3.5-9)	Aggradation reduces fish access and migration.	Dredge from RM 3.5 to RM 9 (intermediate mainstem dredge). Includes placement of LWD in dredged reaches.
9	Side Channel Reconnection	Rearing and migration opportunities are significantly limited in this remnant river channel with a poor connection to the mainstem.	Reconnect abandoned side channel between RM 4 and 5.6 to provide high flow refuge and rearing habitat for fish.
26	Dips Road Setback	West Valley Road (located at the "Dips") acts as a physical barrier to riparian habitat connectivity.	Relocate a small area of West Valley Road in the vicinity of the Dips to provide additional floodplain habitat and reduce the stranding potential for fish.
28	River Mile 9 Setback Levee	The connection to riparian habitats is restricted by a levee near the mainstem bank.	Construct setback levee near RM 7.5-8 to provide additional floodplain habitat and to reduce the stranding potential for fish. Breach existing levee at four locations to allow flood waters to flow freely within the levee setback area, providing salmon access to the riparian habitat.
35	Upstream LWD Installation	Spawning, rearing, and refuge habitats (including pools) are limited in RM 9 to 11 due to a lack of large woody debris in the upstream reaches of the Skokomish River.	Place and install large woody debris from RM 9-11 to increase meandering and bar formation and provide cover for salmon.
37	Grange Levee Setback	The connection to riparian habitats is restricted by the Grange Levee near the mainstem bank.	Construct setback levee near RM 8.3-9.2 to provide additional floodplain habitat and to reduce the stranding potential for fish. Breach existing levee at two locations to allow flood waters to flow freely within the levee setback area, providing salmon access to the riparian habitat.
39	Hunter Creek Mouth Restoration	There is a poor connection between the mouth of Hunter Creek and the mainstem.	Small-scale excavation at the mouth of Hunter Creek to provide year-round access between the Creek and mainstem river in the vicinity of RM 6.5.
40	Hunter Creek Tributary Restoration	Fish stranding commonly occurs at this site due to limited side channels off of Hunter Creek; spawning and rearing opportunities are significantly limited in Hunter Creek.	Construct tributary channels to Hunter Creek to provide additional fish rearing and refuge habitat.
43	Weaver Creek Tributary Restoration	A lack of juvenile salmonid rearing habitat & stranded fish during high flow events.	Construct tributary channels to Weaver Creek to provide additional fish rearing and refuge habitat.

1.3 River Mile Notation

River Miles changed in during the development of conceptual design. Initially the PDT defined river miles according to the H&H HEC-RAS model, presented in the map below as Model River Miles. The development of estimated quantities and costs were based on the model river miles. River miles referenced in this appendix refer to model river miles. The river miles adopted for plan formulation of the final array are as defined by the Bureau of Reclamation, presented in the map below as Project River Miles. A map presenting both sets of river miles is presented below.

Figure 2. River Mile Notation



1.4 DESIGN FEATURES

Table 1-3 summarizes the project features developed in preparation of the conceptual design alternatives.

Table 1-3. Design Features

Project Feature	Description of Project Feature	Approx. Quantity
Base #1	Dredge Skokomish River from River Mile 0 to River Mile 9	2,684,000 CY
Base #5	Dredge Skokomish River from River Mile 3 to River Mile 5	1,870,000 CY
Base #2	Confluence River Dredging River Mile 7.3 to River Mile 8.8	150,000 CY
Car Body Degrade	Remove Existing Car Body Levee. For cost estimating purposes we are assuming the car body levee is comprised of earthen material and the possibilities that the levee is constructed with debris is included in the cost risk contingency.	23,200 CY
Dips Road Degrade	To increase flood plain connectivity, where the road embankment is higher than the adjacent ground the asphalt and roadbed material would be removed. Where the road is lower than adjacent ground only the asphalt pavement would be removed.	1,800 CY
Dips Road Relocation	The new road would follow the alignment #2 provided by Mason County on 13 November 2012, ref. Engineering Annex below. The vertical alignment of the roadbed would be raised	11,556 CY Fill 10,120 CY Cut

Project Feature	Description of Project Feature	Approx. Quantity
	1 foot above the adjacent ground.	
Existing Grange Levee Degrade	Degrade two sections of the existing Grange Levee to match existing grade.	5,220 CY
Grange Levee Setback	Setback Grange Levee south up to 1,200 ft , RM 7.5-8, to provide additional floodplain habitat.	23,500 CY
Large Levee Degrade	Degrade four sections of the existing Large Levee to match existing grade.	6,000 CY
Large Levee Setback/ River Mile 9 Setback levee	Setback Large Levee, RM 8.3-9.2, to provide additional floodplain habitat	20,000 CY
Large Woody Debris Placement	The two large excavation bases would target 64 logs per mile, with more at the mouth. Dredging may also require the construction of 6-8 larger LWD jams to provide bank protection for high erosion risk sites near RM's 6 and 7. The South Fork would also target 64 logs per mile between RMs 9 and 11.	60-70 single logs per mile
Sediment Trap	Sediment Trap to be located upstream of RM 9 for sediment management. The sediment trap is a proposed O&M feature associated with Base #3 and is not included in the Tentatively Selected Plan.	58,300CY Cut 9,500 CY Riprap 22 Logs for Log Jams
Side Channel #9	The abandoned channel that exists between RM's 4 and 5.6 would be reconnected to the main stem to provide high flow refuge and rearing habitat for fish. The proposed depth and volume of cut varies with the selected Base.	8,500-16,000 CY
Weaver and Hunter Creeks Side Channel & Mouth Excavations	The proposed restoration at Weaver and Hunter Creeks would consist of excavating small channels along existing swales and at the creek mouths down to slightly below the water table to provide additional fish rearing and refuge habitat	148,060 CY

1.5 Staging and Access

Based on evaluation of the site topography and predominant land use the PDT assumed it will be possible to procure staging areas of approximately 100' x 100'. The PDT assumed approximately 30,000 SF of staging areas would be cleared and grubbed, for each base. Base #3, Car Body Levee Removal, is the only base for which the access to the staging areas and site is a significant distance from main road access. For all of the other bases, staging areas were assumed to be adjacent to the main road and the construction entrances were assumed to be incidental and covered under the staging area construction. With regard to Base Alternate 3, based upon Autodesk QTO and Google earth approximately 7,250 LF of temporary roads are assumed to be needed for the purposes of hauling and excavating between the highway and the staging areas, and a 12' wide temporary bridge will be needed to cross the north fork of the river for access. We assumed that a temporary bridge will be needed as a longer haul route along the levee could substantially lower production and increase project costs. No permanent access roads are anticipated. Haul Distances are assumed to be between 10 to 20 miles. Further details can be found in the Cost estimating portion of the draft feasibility report.

1.6 General Construction Methodology

GENERAL

We assume specific timing restrictions will be required for in-water work to protect fish and wildlife and measures may be required under site-specific permit requirements to protect downstream infrastructure. The erosion and water quality control plan and best management practices will be determined during PED.

CONSTRUCTION METHODOLOGY

For cost estimating and screening purposes we assumed equipment that will likely be required for construction. Specific to Bases 1 and 5, we assumed a 16" cutterhead pipeline dredge would be used to excavate river miles 0-1 and 4 CY dragline cranes would be used from river miles 1-9. Off-road dump trucks would be used to transport dredged material from the river channel to a staging area. At the staging area the excavated material will be processed through a screener to remove large cobbles not suitable for placement through a pipeline dredge. Following screening, a 3.2 CY loaders located at the staging areas would remove stockpiled dredged material and load 12 CY standard dump trucks for highway transport. The highway dump trucks would transport excavated material from staging areas to the mouth of the river along county roads. A 30'x30' temporary loading dock could be constructed at the mouth of the river f which the highway trucks would deposit excavated material. A loader in place at dock would dump material at the end of dock to feed a pipeline cutterhead and a pipeline dredge would deposit material evenly throughout the shoals. The resulting impacts to Anna's Bay estimated for the largest dredging base, Base 1, would likely fill an average of 2-Feet in height for an area approximately 866 Acres.

In general for cost estimating purposes we assumed 3.2 CY front end crawler loaders, tracked 2 CY excavators and 6x6 articulated frame 18 CY trucks for off-road work and 12 CY standard dump trucks for highway hauling.

Specific to Base 2, Confluence River Dredging River Mile 7.7 to River Mile 9.4, we assumed a 2 CY Hydraulic excavator would work in the channel with silt protection for all excavations. Off- road dump trucks would deposit excavated material at the staging areas. It is assumed that the channel will be navigable by trucks and no built up roads would be required. Loaders at the staging area would stockpile and load highway dump trucks for disposal highway to a local quarry/ disposal site. For screening purposes and based upon GIS searches we assumed a quarry site could be found for disposal within 10 miles.

For Base 3 the Car Body Levee Degrade and the increments, we assumed Hydraulic excavator would load material into off-road dump trucks and the same assumptions for loading and disposal as the bases listed above would be applicable.

Construction equipment assumed for the increments include 2 CY crawler excavators, and log skidders for the LWD installation and HP dozers for the levee setbacks. Construction equipment we assumed for the Dips road increment includes a wheel loader excavator pulverizer, vibratory double drum rollers HP grader, HP crawler dozer and an asphalt paver.

1.7 Risk and Future Studies

A LiDAR and Photogrametry-based topographic surface model was used in developing the conceptual design. However, LiDAR and Photogrametry does not include bathymetry and in areas obscured by thick vegetation and for smaller features, the accuracy and precision of the elevations in that surface model are questionable.

The risk to the project if the error/uncertainty in those elevations would be expressed in terms of earthwork quantities and in site access. The cost estimating effort is informed by a risk based approach . Higher-resolution field topographic surveys would be required to complete modeling and proceed with the development of project designs.

The risk to the project should the disposal assumptions should be incorrect is that the cost would increase. Feasbility effort will include further investigation to establish the availability of disposal. During the next phase of feasibility design, for an example, we will investigate the composition of the carbody levee to determine suitable disposal for earthen material and potential encountering carbody debris

Additionally, should the dredging from rivermiles 0-9 be furthered there is a risk that design and analysis will uncover the potential for impacts to existing bridge abutments and utility crossings that would necessitate design refinements and costs not captured those potential impacts or design changes are not included in the current phase.

Additional information will be required at during design to confirm the design assumptions, refine quantity estimates, address property and regulatory issues, and fill in data gaps.

Topographic/Bathymetric survey data will be required during design to refine design of key project elements, confirm that target elevations are appropriate and develop detailed construction and demolition plans. Survey data could also be used as a baseline for pre- and post-construction modeling, including hydrodynamic modeling.

Utility Survey: Detailed information on utilities are needed to finalize the design and confirm acquisition requirements.

Parcel ownership and property boundaries will be needed to finalize the design, confirm acquisition requirements, and support negotiations with property owners.

1.8 GIS TOPOGRAPHY

Four different data sources were used to develop a topographic surface for 2D mesh development:

1994 Photogrammetry 2-ft Contour Map
- Source: Bell Walker & Associates
- Description: A Photogrammetry model was built with a stereoscopic drafting station using GPS registered aerial photography. Extends upstream to approximately RM 1 on Vance Creek and 11 on Skokomish River.

2002 Bare-earth LiDAR
- Source: Puget Sound LiDAR Consortium
- Description: Bare-earth LiDAR containing the X, Y, Z values of all the LiDAR returns classified as ground.

2007 In-channel ground survey of Skokomish River
- Source: USACE, October 2007
- Description: Top of bank to top of bank cross section surveys from RM 10 to 2.

2009 In-channel ground survey of Vance Creek
- Source: Bureau of Reclamation, July 2009
- Description: In-channel cross-section data for RM 0 to 4 of Vance Creek. Generally does not include top of bank.

To develop the topographic surface, the 1994 Photogrammtery contour data was used as the baseline data set. The 1994 Photogrammtery data set was specified by USACE instead of the 2002 LiDAR data because of concerns that the LiDAR did not have a thorough post-processing effort to remove vegetation. The 2009 model report reported that the model mesh built from the LiDAR dataset typically had a water surface elevation about 1 foot higher than the model mesh built from the Photogrammetry dataset. In addition, the bank elevations in the LiDAR data are higher because the vegetation was removed and the higher bank elevations increase the computed conveyance in the main channel. The Photogrammetry is considered to have a more accurate representation of the channel bank elevations, relative to 1994 conditions.

Where photogrammetry data was not available within the mesh boundary, such as above RM 1on Vance Creek, the bare-earth 2002 LiDAR data was used. The following refinements were then made before generating a continuous above and below water surface in a geographical information system (GIS):

The below water portions of the Skokomish River and Vance Creek were delineated and photogrammetry and LiDAR data within these bounds were deleted.

For the mainstem Skokomish River, the photogrammetry contours were replaced with a set of channel elevation points based on the 2007 cross-section data and interpolated points between cross sections (Klumpp and Bountry, 2009).

For Vance Creek, the photogrammetry contours and LiDAR data were replaced with a set of channel elevation points based on the 2009 cross-section data and interpolated points between cross sections.

Between RM 2 and 0, where no channel survey data was available, topographic elevations were estimated by creating a sloped channel that smoothly transition from 6 ft at RM 2 to 0 ft at RM 0.

At the Purdy Creek bridge embankment, a design drawing provided by USACE (generated by WDOT) was used to estimate the stream geometry after the bridge was completed in late 2009. No as-built data was available, and, therefore, photogrammetry was utilized for the side channel which does not include the channel elevations below water.

In summary, the limitations of the topographic data sets are:

- No survey data was available for the below water portions of the Skokomish channel downstream of RM 2.
- No survey data was available for the North Fork that represents recent channel changes or wetted areas.
- Hydraulic controls (riffles) on the mainstem channels that influence water surface elevation may have been missed if they were not captured by the cross-section surveys.
- In many densely vegetated areas LiDAR data did not have vegetation removed in the bare earth model.
- Photogrammetry data is over a decade old.
- Channel survey data was not available for wetted areas of the floodplain, including Purdy Creek, Weaver Creek, and Skabob Creek. Some 1D cross- sections are available but are over a decade old and the original survey data could not be located to geo-reference the information.

Preliminary roadway sections are based on Mason County Criteria. Reference the annex for further details.

2 GEOTECHNICAL DESIGN

2.1 GEOLOGY

The Skokomish River Valley is located at the southeastern end of the Olympic peninsula near the southernmost extent of the Hood Canal. The Skokomish River flows east from its headwaters in the Olympic Mountains and descends through narrow steep gorges and cascading pools to the Skokomish Valley, which occupies the lower most 10 miles of the Skokomish drainage.

The Puget Lowlands have been impacted by multiple continental glaciations during Pleistocene time. The ice excavated the valley during the Vashon stade into the older Vashon advance outwash deposits (Great Lowland Fill) and pre-Vashon deposits (Booth, 1994). Holocene fluvial erosion has exerted minimal influence on the large-scale valley morphology.

The Skokomish catchment is underlain by thick deposits of glacial till and inter-glacial gravel, which is, in turn, underlain by basalt (Carson, 1970; Tabor, 1975). The lower portions of the basin consist of till deposited by the Vashon lobe of the Fraser Glaciation approximately 15,000 years ago. In the valley of the mainstem Skokomish, interglacial gravel interfingers with Holocene fluvial deposits of the Kitsap Formation. Eocene basalt outcrops in upper portions of the basin, in the gorge. (Channel change and flooding, Skokomish River, Washington, Journal of Hydrology, S.C. Stover & D.R. Montgomery, 15 December 2000).

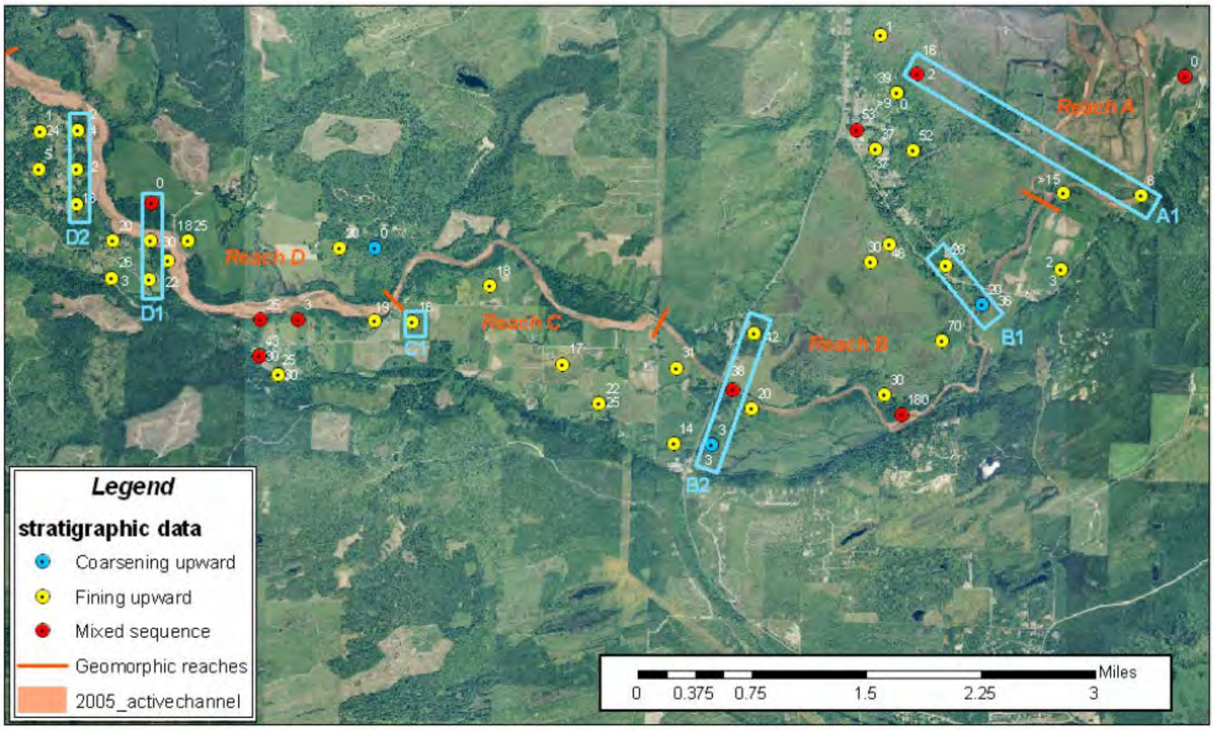
2.2 EXISTING SUBSURFACE EXPLORATIONS AND SOIL CLASSIFICATION

A study entitled, “Miscellaneous Planning Studies: Skokomish River Diking Inventory” dated April 2001 and prepared by HDR Engineering, Inc. provides four test pits and soil classifications near existing levee sections. Test pits were excavated with a Cat 416B backhoe and samples were delivered to Hammond, Collier & Wade-Livingstone for soil classification. Test pits were dug to a depth between 6 and 9.5 feet below ground surface. The results of these laboratory tests showed Silty SAND with gravel (SM) and SILT (ML), non-plastic, liquid limit (LL) in the range of 25 to 35, and moisture content ranging from 9% to 30%. The depth of top soil was approximately 3.5 feet. Organic debris was noted to a depth of 5 feet in TP-3.

The Natural Resource Conservation Service (NRCS) provide a web soil survey that provides information about the soils in a specific project area. For the initial stages of this project and the lack of existing soil data, the NRCS Soil Survey was used to inform general assumptions about the soils and their suitability for projects. The foundation for the levee setback projects has been delineated by NRCS as “Dg, Dungeness Fine Sandy Loam” with a USCS soil classification of “SM, Silty Sand.”

Another source of existing subsurface data comes from the Department of Ecology’s well log system. A report entitled, “Geomorphic Analysis of the Skokomish River, Mason County, Washington” prepared by the Bureau of Reclamation, performed a detailed analysis of sediment deposition trends.

Figure 2-1. Well Log Survey



2.3 EXISTING GROUNDWATER STUDIES

A study entitled, "Miscellaneous Planning Studies: Skokomish River Diking Inventory" dated April 2001 and prepared by HDR Engineering, Inc. notes typical groundwater trends. "The groundwater table in the valley has been reported to be rising over the last thirty years. The groundwater level in the upper valley [upstream of Skokomish Community Church near RM 8.25] is typically 0.5 to 3.0 feet below grade." (12). During high water, the groundwater has been seen percolating from old river channels. The report continues, "current groundwater flows are away from the river and run with a light silty mud present in the water" (12). No additional groundwater data or studies were available for review.

2.4 EARTHQUAKE STUDIES

The Skokomish River Valley has a seismic site classification of D to E based on Washington State Department of Natural Resources Liquefaction Susceptibility and Site Class Maps of Washington State, by County (2004). The DNR maps also classified the liquefaction susceptibility of the river valley as moderate to high.

Earthquake loadings are not normally considered in analyzing the stability of levees because of the low risk associated with an earthquake coinciding with periods of high water. The severity of the expected earthquake and the consequences of levee failure are considered. The assumed loose silty sands composing the levee foundation have liquefaction potential, but seismic design is not anticipated for this site based on low coincident loading probability and low expected consequences

2.5 DESIGN CONSIDERATIONS: INCREMENTS

2.5.1 Grange Levee Setback Design Considerations

The new levee would be around 2,900 ft long and would provide a similar level of flood risk reduction. The Grange levee setback conceptually involves four distinct levee sections based on change in elevation from 5-foot typical to 7.5-foot typical, tie-in to existing road, and spatial constraints from existing structures. Given stationing from upstream to downstream, the levee would transition from the existing levee to a setback levee of approximately five feet in height. Typical levee crown width is 12 feet and the typical riverside slope to allow for sod erosion protection is 3H:1V. Channel velocities are assumed to be minimal; not requiring typical "hard" riverside erosion protection such as riprap. The entire levee segment would be designed for shallow overtopping.

Initial shear stress calculations dictate a 6H:1V landward slope to sustain overtopping flows for limited durations with only good sod cover. This typical levee section (Section 1) will be used from station 0+00 to station 9+00. This section (Section 2) will transition to a section of similar proportions but, of 7.5 feet height between stations 9+00 to 12+00. Near station 12+00, the setback levee will tie into the existing W Skokomish Valley Road by raising the road to function as a levee (Section 3). The conceptual design assumption is that seepage will not be a concern given the 28-foot typical roadway section. This will need to be analyzed during E&D. Roadway transitions at a 2 percent slope will be required to tie the existing roadway into the raised roadway. Therefore, modifications 100-200 feet east and west of this raised section will be required. Near station 15+00, the levee will transition into its fourth distinct section: a reduced width section due to the spatial constraint of a private residence structure. There is not currently sufficient space to have a full sod overtopping section. The landside slope will be reduced to a 2H:1V slope and a 12-inch blanket of quarry spalls will be placed to provide sufficient overtopping resistance. This design will need to be confirmed during E&D. High performance turf reinforcement mats (HPTRMs) will be investigated during future engineering and design as a viable alternative for the overtopping sections. Previously described Section 1 will be constructed from Station 19+00 to Station 27+00. Section 2 will be constructed from Station 27+00 to the transition with the downstream existing levee near Station 30+00.

2.5.2 Hunter and Weaver Creeks Design Considerations

The tributary channels were conceptually designed to mimic the existing channels. Existing Lidar was used to determine existing side slopes of approximately 2.5H:1V. No specific soil information was available at this stage to analyze the slope stability of the new channels. Test pits in the area of the proposed channels will feed into basic slope stability analyses during future engineering and design. Temporary erosion control features will also be explored in future design phases to arrest any slope erosion while vegetation establishes in the new tributary channels.

2.5.3 Large Levee Setback Design Considerations

The new large levee setback from RM 8.3 to 9.2 is expected to be approximately 4 feet in height. The total length of setback levee is approximately 4500 linear feet. The levee crest width is 12 feet wide with 3H:1V riverward slopes and 6H:1V landward slopes to allow for overtopping flows. The entire levee would be designed for shallow overtopping, but a length of levee between RM 8.8-9.0 would be a designed overflow section, with a slightly lowered crest, to maintain the flood pattern similar to what occurs presently. High performance turf reinforcement mats (HPTRMs) will be investigated during future engineering and design as a viable alternative for the overtopping sections. The levee will be designed for adequate superiority for controlled overtopping consistent with ETL 1110-2-299.

2.5.4 Dips Road Setback Design Considerations

The Dips Road relocation, RM 9.5-9.7, conceptual design was heavily based on existing information and existing Mason County road sections. An average daily travel (ADT) count on West Skokomish Valley Road from July of 2009 totaled 992 vehicles; although no vehicle type distribution was provided. Based on initial assumptions, the typical Mason County pavement section appeared appropriate for a conceptual design. The travel lanes were conservatively assumed to be 12-foot wide instead of the typical 11-foot because of an unknown road alignment curvature. The road section can be reduced if applicable during future engineering and design.

Due to uncertainty of the foundation soils, the conceptual design road base foundation was estimated to have unsuitable and organic soils to a depth of approximately 24" to 36" below grade. This material will be removed and replaced with suitable foundation soils. The scope of over-excavation will be determined from future subsurface soil exploration.

2.6 Risk, Next Steps, and Future Studies

2.6.1 Risk

Assumptions about soil conditions without soil testing may lead to a design and footprint of projects that could underestimate the soil conditions requiring an increase in design effort as well project cost. Future levee exploration and soil testing along project alignments as well as identifying potential borrow sources based on anticipated soil quantities will reduce the risk of design and cost errors.

2.6.2 Levee Exploration & Testing

The spacing of borings usually varies from 200 feet to 1,000 feet along the alignment, being closer spaced in problem areas and wider spaced in non-problem areas. The depth of these borings should be sufficient to account for modeling needs. Approximately 3 times the levee height or 30 foot minimum depth should be sufficient. Test pits can be as deep as the levee height but not less than 10 feet.[1]

Preliminary strength estimates can be estimated from standard penetration testing.

Laboratory testing should include Atterberg limit testing for fine-grained soils, visual classifications, organics, and grain size analysis (gradation). Consolidation and/or shear strength testing could be done if design requires or if soils are weaker than expected.

A subsurface exploration plan, scope of work, and an estimated laboratory testing schedule should be developed.

2.6.3 Potential Borrow Guidelines

Identifying potential borrow sources for the levee and road construction is a critical next step to assess the project feasibility and to update cost assumptions. For the cost estimate, all excavated soil was assumed to require off-site disposal and all fill was assumed to be imported at a haul distance of 10 miles. These assumptions will be validated during the future feasibility level design phase.

Unsuitable soil includes wet, fine-grained soils or highly organic soils. Almost all other soil types are suitable for levee construction. Accessibility and proximity are controlling factors in selecting borrow sources. The water content of the borrow soil is also a significant factor in selection. The water content needs to be near the soils

[1] EM 1110-2-1913 Design and Construction of Levees

optimum water content to allow for proper compaction. This may affect the construction season. Borrow source volumes should be about 125 percent of the required volume to account for shrinkage, hauling and other losses.

The potential removal of the car body levee at the confluence of the North and South forks of the Skokomish River, left bank, near RM 9.0 could provide a suitable borrow source for other embankment construction. This material should be tested to confirm suitable embankment fill. The car body levee removal is estimated to be approximately 23,200 CY of fill. However, the car body levee may contain car bodies that may reduce the quantity of useable fill.

2.6.4 Summary of Future Steps

1. Subsurface exploration and laboratory testing within conceptual design footprints.
2. Preliminary levee design based on gathered soil information. Perform settlement, seepage, and stability analyses per EM 1110-2-1913: Design and Construction of Levees. Analyze overtopping sections.
3. Preliminary pavement design based on CBR values of proposed subgrade.
4. Pile anchor design for large woody debris (LWD).
5. Selection of available borrow sources. Investigation of car body levee to determine suitability as borrow source.

3 HYDRAULIC DESIGN

Two hydraulic models were utilized for this study. River and floodplain hydraulics were modeled with a two-dimensional model. Bedload transport in the river was modeled with a one-dimensional model.

In 2009, the Bureau of Reclamation utilized SRH-2D, a 2-D hydraulic model, to model floods in the Skokomish River Valley. The SRH-2D software utilizes a dynamic wave solver to route flow through independent mesh cells and can, therefore, handle multiple water surface elevations and flow paths. Model outputs include; the extent and depth of flood inundation, current velocities and directions, and flow distributions. The topographic data used for the Skokomish valley was primarily taken from a 1998 photogrammetric survey, while the bathymetric information for the river was taken from 2007 cross section data. A detailed description of the model and the results are presented in the Skokomish River Basin Flooding and Sedimentation Baseline appendix.

Bedload transport modeling was completed by Seattle District using HEC-RAS 4.1, which incorporates bedload transport equations into a quasi-unsteady 1D flow model of the Skokomish River. The bedload transport function used in this model was the Meyer-Peter Muller (MPM) equation. The model was calibrated to the stage/discharge and bedload measurements at the USGS mainstem gage (RM 4.8). The HEC-RAS model used in this analysis was originally developed by KCM in 1997. It was updated by CES (1999) and WEST (2006). For this bedload analysis USACE again updated the model with new channel cross-section surveys between RM's 2 and 11 in 2007 and RM 0-2 in 2011. Lateral weirs were used along the channel to simulate the diversion of flood waters from the main river channel. Active flow areas were limited to those along the river that influenced the amount of water in the main channel. The bed material gradation is an important model input for the bedload transport calculations. The bed material gradations used in the model were collected by Reclamation in 2009. The bedload transport results were compared to measurements collected at Highway 101 in 1994 by Simons and Associates and in 2010 by the USGS. A detailed description of the bedload transport model and the results are presented in the Skokomish River Basin Flooding and Sedimentation Baseline appendix.

3.1 DESIGN CONSIDERATIONS: BASES

3.1.1 BASE #1: RIVERBED EXCAVATION RM 0-9

Bedload sediment deposition has filled the Skokomish River channels to the levels where flooding now occurs 3-4 times per year. Large woody debris has been cleared from the channels, removing important fish rearing habitat. The RM 0-9 channel excavation base is designed to restore the natural functions of flood conveyance and bedload transport, and allow restoration of lost fish habitat. The base would provide approximately 50% annual chance exceedance (ACE) channel capacity and allow installation of instream LWD structures for fish habitat. The expected reduction in the frequency of overbank discharges should also reduce the occurrence of fish stranding. Ancillary benefits would be a reduction of flood elevations and increased bedload transport to Annas Bay.

The proposed excavation reach starts near RM 0, where the estuary channel enters Annas Bay. The excavation continues upstream to just above the old North Fork mouth at RM 9. Downstream of RM 5, the proposed excavated channel is 150 ft wide and follows the centerline of the river. The side-slopes would generally kept steep at 2H:1V. The depth of cut would vary by cross-section and across the cross-sections. Along the thalweg the depth of cut could range from 0-8 ft, with the depth of cut along the edges reaching up to 20 ft. The average depth of cut would be around 7-8 ft. The excavation required to construct this channel from RM 0-5 would total approximately 1,468,000 cubic yards.

Upstream of RM 5, the channel contains many gravel bars. The proposed dredged channel would be 100 ft wide at the bottom, with the alignment generally following the centerline of the river. The side-slopes would typically be 5H:1V, a more stable slope than the 2H:1V proposed for RM 0-5, but still not equal to the gravel bar side-slopes that approach nearly 10H:1V. The depth of cut would vary by cross-section and across the cross-sections. Along the thalweg the depth of cut could range from 2-8 ft, with the depth of cut along the edges reaching up to 20 ft. The average depth of cut was approximately 11 ft. The dredging required to construct the channel from RM 5-9 would total approximately 1,216,000 cubic yards.

The proposed channel would have a discharge capacity in the range of 17,500 cfs; the peak discharge of a 50% ACE flood. This would be about a 13-15,000 cfs increase from the existing conditions. The proposed excavated channel would reduce the frequency and severity flooding in the valley, but not eliminate it.

The higher in-channel flows could increase bedload transport throughout the excavated reach of the river. There could be a redistribution of deposition within the channel, potentially resulting in more deposition downstream of Hwy 101. The location of minimum bedload transport would continue to exist around RM 3.5, just upstream of the Purdy Creek confluence. Bedload transport to Annas Bay could increase, especially for discharges over 3-4,000 cfs. Most of the potential bedload transport to Annas Bay would come from erosion downstream of Purdy Creek.

Sediment deposition can be expected to continue to occur in this channel for the foreseeable future. The overall deposition rate is predicted to be the same as the without project rate, approximately 35,000 cu yds per year. However, bedload transport would be altered with higher transport rates in the upstream reach and more sediment being transported farther downstream than occurs presently. This would change the sediment deposition distribution, shifting more deposition downstream. Maintenance actions are likely to be required in the future to counter the effects of sediment deposition.

3.1.2 Base #2: North Fork Confluence Dredging

In the vicinity of the North Fork/South Fork confluence, riverbed aggradation in the South Fork and the avulsion of the North Fork has lead to dry channel conditions developing in the South Fork during the late summer/early fall time period. The dry channel stops the upstream migration of salmon returning to the South Fork. This base would lower the river thalweg to provide a continuous low flow channel during the late summer base flow conditions and allow passage of migrating salmon.

The excavation reach would extend from near the current North Fork confluence (RM 7.3) upstream to 2,000 ft upstream of the old North Fork confluence (RM 8.8). The alignment of the excavated channel would follow the existing thalweg to minimize disturbance of the channel form and the excavation volume. The thalweg would be lowered at least 2 ft and up to 5 ft in some reaches. The bottom of the excavation would be 40 ft wide, with the top width ranging from 100 to 160 ft. The side slopes would vary from 2H:1V to 12H:1V, depending on the channel cross-section shape. The gravel bars would be excavated at 10H:1V to 12H:1V to keep the channel form similar to the existing conditions. The total length of excavation would be 7,000 ft. The volume of material to be removed is estimated to be 150,000 cy.

This excavation could increase the discharge capacity of the river channel by about 4,000 cfs and lower flood elevations locally by up to 1 ft. Less flood water would be spilled onto the southern floodplain through this reach. However, the increased discharge carried downstream would aggravate downstream flooding.

Modeling results indicate bedload transport would only change slightly from current conditions. Deposition would continue to occur in the upper 4,000 ft at about the existing estimated rate of 5-10,000 cy/yr. The lower 2,000 ft, just upstream of the North Fork confluence, is a more confined channel and modeling indicates the higher discharges would increase bedload transport in this reach. This could cause some small amount of bed scour upstream of the North Fork confluence.

Periodic dredging would be required to maintain this channel. It is impossible to reliably predict how much of the 5-10,000 cy/yr of deposition expected in this reach will deposit in the excavated channel. Thalweg changes between 1994 and 2007 range from -1 to +6 ft, while the overall bed elevations rose by an average of 1 to 1.5 ft. The excavated channel would be similar in profile to the 1994 channel, so it is reasonable to expect that the deposition will also be similar and occur over the entire river channel. Thus, about half the deposition would occur in the upper 4,000 ft of the excavated channel and maintenance dredging of 25-50,000 cy could be required at about a 10 year interval. The bed material, LWD, and channel alignment in this reach are unstable and minor excavation may be required annually to maintain a continuous low flow channel.

3.1.3 Base #3: Car Body Levee Removal

In the vicinity of the North Fork/South Fork confluence, riverbed aggradation in the South Fork and the avulsion of the North Fork has lead to dry channel conditions developing in the South Fork during the late summer/early fall time period. The dry channel stops the upstream migration of salmon returning to the South Fork. This base addresses that problem by removing the Car Body levee and diverting the South Fork into the North Fork near the pre-2003 confluence. The combined discharges would provide a continuous low flow channel in what is now the North Fork channel. The reach of the South Fork that goes dry in the late-summer/early-fall would be abandoned during those low flow periods. This base would have little effect on flooding since the existing South Fork channel would be available to convey flood discharges and both sides of the river frequently flood in this location already.

Since the 2003 North Fork avulsion, that shifted the mouth downstream about 1.5 miles, the car body levee has been a barrier between the North and South Fork channels. The car body levee is located at and downstream from the old confluence near RM 9. Aggradation in the South Fork channel has raised much of the riverbed to elevations above the North Fork at the old confluence, but the levee limits the flow diversions to the North Fork.

About 4,600 feet of the car body levee, approximately 23,200 cu yds, would be removed. A small channel would be established to direct the South Fork flows into the current North Fork channel. The river channels would then be permitted to naturally evolve over time. The new connection would allow upstream migrating salmon to bypass the reach of the channel that typically goes dry in the late summer. This action would have little impact on flooding, as the North Fork floodplain is frequently inundated by the South Fork flood flows.

Little deposition has been observed in the current North Fork channel. It is expected that the South Fork's bedload would be diverted to the combined channel after levee removal. This is likely to cause increased sediment deposition in the combined channel.

3.1.4 Base #4: Riverbed Excavation (RM 3.5-9)

Bedload sediment deposition has filled the Skokomish River channels to the levels where flooding now occurs 3-4 times per year. Large woody debris has been cleared from the channels, removing important fish rearing habitat. The RM 3.5-9 channel excavation base is designed to restore the natural functions of flood conveyance and bedload transport, and allow restoration of lost fish habitat. The base would improve the late summer connection to the South Fork, reduce overbank flooding and related fish stranding, allow for habitat improvements in 5.5 miles of river channel, and increase bedload transport to RM 3.5. An ancillary benefit would be to reduce flood risk in the upper valley.

The downstream limit for this shorter excavation base was chosen because it will convey the design discharge and associated bedload to a point where floodwaters currently re-enter the main channel. To assure the late summer connection to the South Fork, excavation would continue upstream past the old North Fork confluence to RM 9.

The excavation alignment would generally following the centerline of the river. Downstream of RM 5, the proposed excavated channel would be 150 ft wide and the side-slopes would generally be 2H:1V. Upstream of RM 5, the proposed dredged channel would be 100 ft wide at the bottom and the side-slopes would typically be 5H:1V. Along the thalweg the depth of cut could range from 0-8 ft, with the depth of cut along the edges reaching up to 20 ft. The average depth of cut would be around 9-10 ft. The excavation required to construct this channel would total approximately 1,900,000 cubic yards.

Sediment deposition can be expected to continue to occur in this channel for the foreseeable future. The overall deposition rate is predicted to be the same as the without project rate, approximately 30,000 cu yds per year. However, bedload transport would be altered with higher transport rates in the upstream reach and more sediment being transported farther downstream than occurs presently. This would change the sediment deposition distribution, shifting more deposition downstream. Maintenance actions are likely to be required in the future to counter the effects of sediment deposition.

3.2 Design Considerations: Increments

3.2.1 Grange Levee Setback design Considerations

The Grange levee setback, RM 7.5-8, is intended to provide additional floodplain habitat and to reduce the stranding potential for fish. The levee would be moved landward (south) up to 1,200 ft. This would place about 40 acres of riparian habitat, forest and floodplain ponds, on the riverward side of the levee. Two strategically selected sections of the existing levee summing to approximately 800 ft would be breached. These breaches would allow flood waters to flow freely within the levee setback area, providing salmon access to the riparian habitat.
The new levee would provide a similar level of flood risk reduction as the existing levee. The height of the setback levee could be lower if one of the large dredging bases (Bases 1 or 5) is the selected base plan. The dredging would increase channel capacity and reduce the flood risk to the valley. The height of the setback levee could be adjusted to provide a flood risk reduction comparable to the existing levee.

3.2.2 Large Woody Debris Structures Design Considerations

LWD structures are planned as increments to all the bases; specifically for the South Fork between RMs 9 and 11, in the new Car Body Levee Removal channel, and in both river excavation bases. A target of 64 “key” LWD pieces per mile was selected, with a minimum of 21 key pieces per mile being acceptable. Key LWD pieces would be 2-3 ft in dia and 15-30 ft long, and should have a rootwad. Species should mainly be conifers; however, cottonwoods are easily acquired and can be used to start collecting other debris. The LWD shall be anchored with stones to prevent them from moving during bankfull discharges. Small LWD jams would be placed to increase channel complexity and provide cover for salmon. The LWD jams would have small cross-sectional areas and be built parallel to flow to minimize the hydraulic disturbance. The LWD would be placed to create a meandering channel near the center of the active high-flow channel that would avoid erosion impacts along the river banks. Some LWD may be used to reduce the risk of harmful bank erosion.

3.2.3 Hunter and Weaver Creeks Design Considerations

This measure involves the construction of tributary channels to Hunter and Weaver Creeks to provide additional fish rearing and refuge habitat. Additionally, the mouths of both creeks may require excavation to provide fish access to improved habitat. Both creeks are perennial groundwater fed streams. The proposed restoration would consist of excavating small channels along existing swales down to slightly below the water table. The Hunter Creek channels would have a 4 ft bottom width and approximately 5 ft depth. The Weaver Creek channels 4 ft bottom width and approximately 5 ft depth. All excavated channels would have 2.5H:1V side slopes. The total length of channel would be approximately 21,250 ft on Hunter Creek and 27,110 ft on Weaver Creek. Bedload deposition is highly variable, but it is estimated that 50-100 cu yds would need to be excavated at the mouths of Hunter and Weaver creeks.

3.2.4 Large Levee Setback Design Considerations

The large levee setback, RM 8.3-9.2, is intended to provide additional floodplain habitat and to reduce the stranding potential for fish. The levee would be moved landward (south) varying distances, generally around 200-300 ft. This would place more riparian forest and floodplain ponds on the riverward side of the levee. Four strategically located sections totaling approximately 950 ft section of the existing levee would be removed. These breaches would allow flood waters to flow freely within the levee setback area, providing salmon access to the riparian habitat. The new levee would generally be lower than the existing levee (typically 4 ft vs. 5-7 ft), but the breaches would be closed to reduce the frequency of fish stranding. The entire levee would be designed for shallow overtopping. A length of levee between RM 8.8-9.0 would be a designed overflow section, with a slightly lowered crest, to maintain the flood pattern similar to what occurs presently. For the smaller confluence bases (Bases 2 and 3) the overflow would be designed to function for 2-yr and larger floods. For the larger dredging bases (Bases 1 and 5), the overflow could be designed to function for perhaps 10-yr or larger floods.

3.2.5 River Channel Reconnection RM 4-5.6 Design Considerations

An abandoned channel that exists between RM’s 4 and 5.6 would be reconnected to the main stem to provide high flow refuge and rearing habitat for fish. The 1935 Skokomish River Valley map shows this channel was an overflow channel, connected to a downstream meander that was later cutoff from the river. The existing channel is narrow and sinuous, with plentiful riparian vegetation and adjacent wetlands. Restoration would involve constructing improvements to the channel inlet and outlet, while most of the channel would not be disturbed. The reconnected channel would only be connected to the river during high discharges and would not convey water year round. During high river discharges the reconnected channel would provide a low velocity refuge. During most of the year the channel would provide pond habitat for fish rearing. Reconnecting the channel to the river could provide 45 acres of high quality, low velocity fish habitat.

Improving the hydraulic connection of the channel to make it more accessible for fish would involve improvements to both the inlet and outlet. A new inlet would be excavated that would only be active when discharges exceed approximately 4,000 cfs, well above winter base flow levels. The inlet would be designed to prevent the river from “capturing” (permanently diverting into) the high flow channel. At the downstream end, the channel would have to be reconnected to the old meander. This connection may be broad and shallow, to allow fish passage during higher river discharges, but not lower the water table in the adjacent wetlands during low flow periods. If necessary, log weirs could be used to control the outlet.

This measure could be implemented with any of the four bases being considered. For the existing conditions the inlet would exit the river at elevation 31 ft NGVD 88. The channel would have a 50 ft bottom width, with 2H:1V side slopes. The depth of cut would vary from 0-5 ft and be near 2,000 ft long. The outlet channel would be approximately 160 ft long, with an invert of 23 ft NGVD88 and a 30 ft bottom width. The depth of cut would vary from 0-3 ft.

The inlet channel would need to be deeper to be compatible with the deeper dredged channel bases, but the outlet would be the same as for existing conditions. To match the dredged channels of bases (Bases 1 and 5), the inlet would have an invert of approximately 28 ft NGVD88, with the depth of cut varying between 0-6 ft.

3.2.6 Dips Road Setback Design Considerations

The Dips Road relocation, RM 9.5-9.7, is intended to provide additional floodplain habitat and reduce the stranding potential for fish. A 0.7 mi section of the road between the Vance Creek and Swift Creek bridges, would be relocated about 400 ft landward (south). This would place 17 acres of riparian forest on the riverward side of the road.

3.2.7 South Fork Sediment Trap Design Considerations

A sediment trap has been identified as a potential operations and maintenance (O&M) feature associated with Base #3, Car Body Levee Removal. The sediment trap would be capable of trapping the annual bedload inflow of approximately 25-30,000 cubic yards (CY). A good location for a sediment trap on the South Fork is between RM's 9.6 and 9.8, 2,000 ft upstream of Vance Creek. The active riverbed is over 350 ft wide in this reach, allowing for construction of the trap without impacting the riverbanks. A 1,600 ft long sump, 3-4 ft deep with a 100-ft bottom width could be dug through this reach. A 3 ft deep sump requires approximately 35,000 cy of excavation to construct and would have a trap capacity of around 20,000 cy/yr. A 4 ft deep sump would require approximately 50,000 cy of excavation and could trap about 25,000 cy/yr. Annual maintenance would be necessary would have to remove the trapped bedload.

The steep slope (12-14 ft/mi) and unstable nature of the South Fork channel will require scour protection at the upstream end of the sump to prevent headcutting. A log and/or rock weir with large end structures could be used to control erosion and keep the river directed into the sump. Some of the excavated material could be used to fill an existing side channel to prevent flow from bypassing the sump. It may also be necessary to construct bank protection to prevent the channel from meandering outside of the sump. There is the potential for scour downstream of the sump for several years. The erosion is likely to occur between the sump and RM 8.8, the upstream end of the deposition zone around the old North Fork confluence.

While the sediment trap was identified as a potential O&M feature for Base #3, it was not carried forward to the Cost Effectiveness/Incremental Cost Analysis (CE/ICA) completed on the Focused Array of Alternatives. This feature would have limited long-term effectiveness in the Skokomish River and is cost prohibitive in terms of initial construction cost and yearly maintenance.

3.3. Risk and Future Studies

3.3.1 Risk

The Skokomish River is very active within the proposed project area. Bedload deposition continues to raise the riverbed, causing the river to migrate across the active channel. LWD jams can also cause the river to migrate, even during a single storm. The elevation and alignment of the river is likely to change before final design, and could change between final design and construction. The level of effort to construct the project may increase due to the alignment of the channel.

Detailed hydraulic modeling of the alternatives has not been conducted. Levee heights and bedload deposition impacts may be inaccurately defined. Project performance goals may not be achieved if levees are undersized or deposition is greater than expected.

Groundwater levels are not well defined. New tributary channels have been sized assuming the water table is approximately 4 ft below ground surface. A deeper water table would increase excavation volumes.

3.3.2 Future Studies

New surveys, LiDAR and/or ground, of the riverbed and adjacent overbanks will be necessary for final design. The area to be covered depends on the alternative selected.

Hydraulic and bedload transport modeling, incorporating the new survey data, is necessary to define channel and setback levee alignments and dimensions.

Ground water levels along the proposed tributary channels need to be defined.

ANNEX TO ENGINEERING APPENDIX

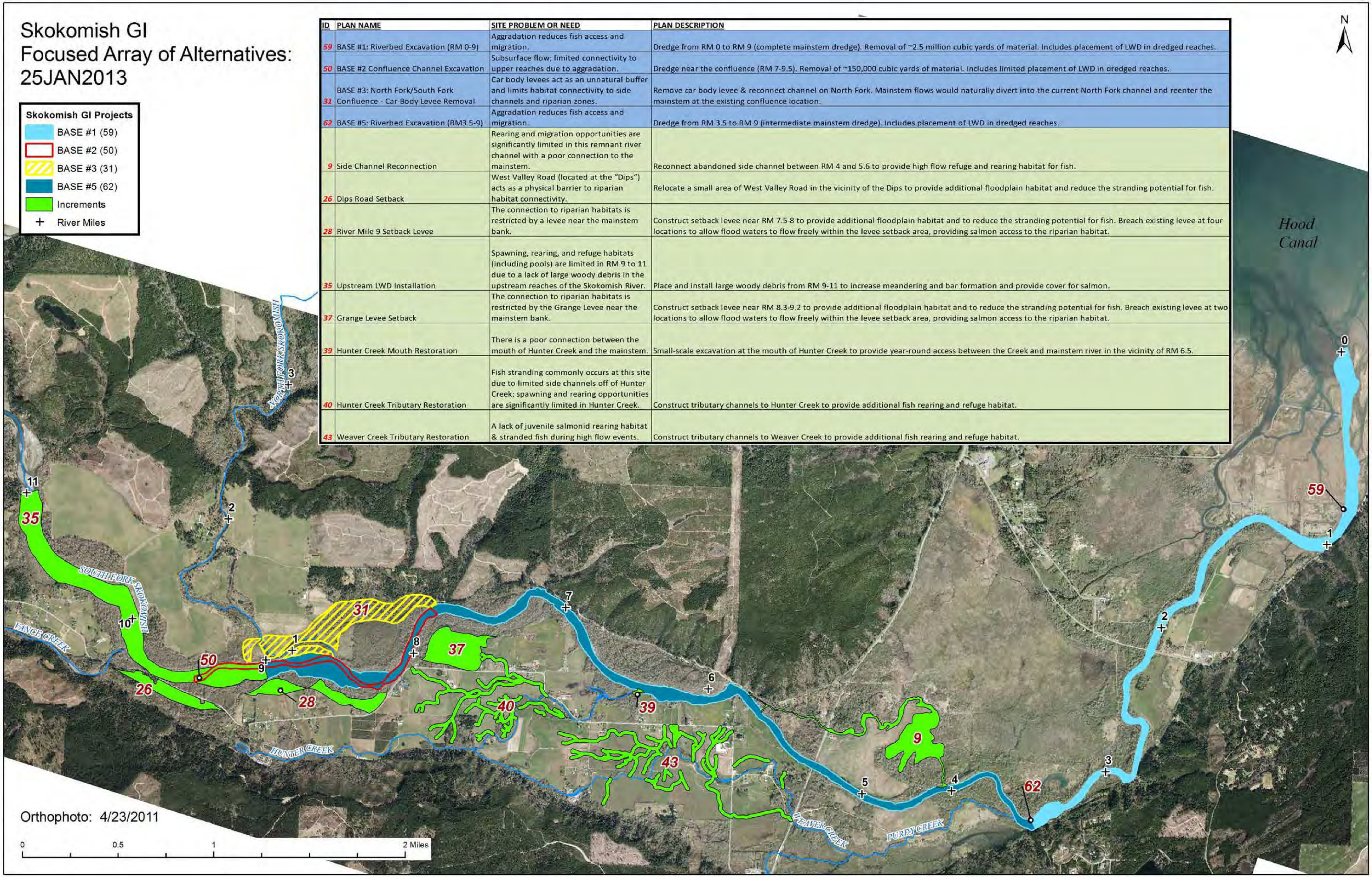
Civil Design Calculations

ANNEX TO ENGINEERING APPENDIX

TABLE OF CONTENTS

Skokomish GI
Focused Array of Alternatives: 25JAN2013

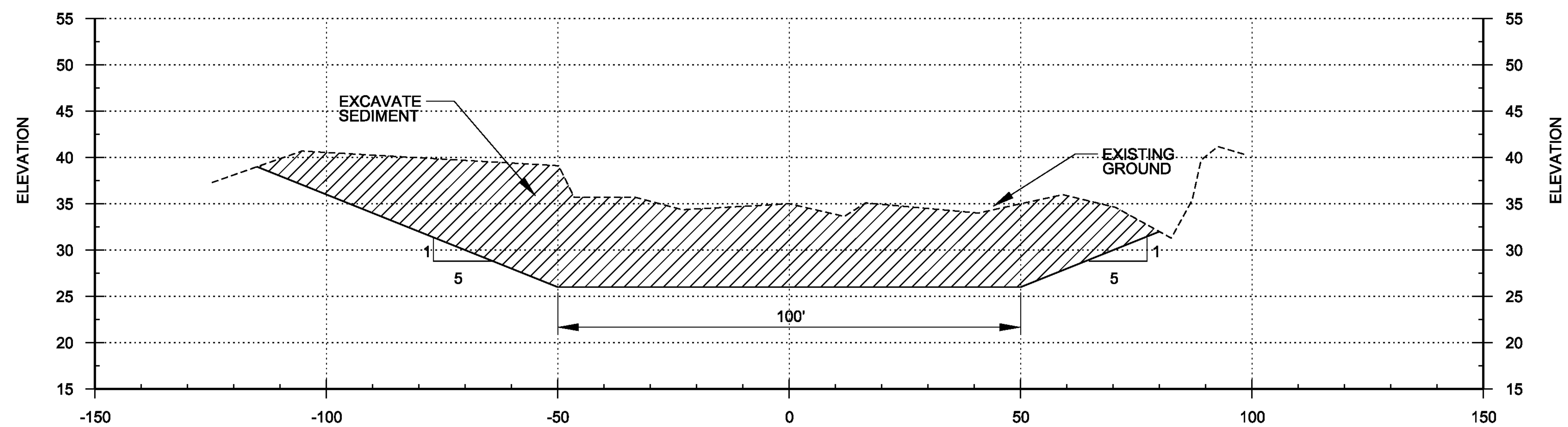
ID	PLAN NAME	SITE PROBLEM OR NEED	PLAN DESCRIPTION
59	BASE #1: Riverbed Excavation (RM 0-9)	Aggradation reduces fish access and migration.	Dredge from RM 0 to RM 9 (complete mainstem dredge). Removal of ~2.5 million cubic yards of material. Includes placement of LWD in dredged reaches.
50	BASE #2 Confluence Channel Excavation	Subsurface flow; limited connectivity to upper reaches due to aggradation.	Dredge near the confluence (RM 7-9.5). Removal of ~150,000 cubic yards of material. Includes limited placement of LWD in dredged reaches.
31	BASE #3: North Fork/South Fork Confluence - Car Body Levee Removal	Car body levees act as an unnatural buffer and limits habitat connectivity to side channels and riparian zones.	Remove car body levee & reconnect channel on North Fork. Mainstem flows would naturally divert into the current North Fork channel and reenter the mainstem at the existing confluence location.
62	BASE #5: Riverbed Excavation (RM3.5-9)	Aggradation reduces fish access and migration.	Dredge from RM 3.5 to RM 9 (intermediate mainstem dredge). Includes placement of LWD in dredged reaches.
9	Side Channel Reconnection	Rearing and migration opportunities are significantly limited in this remnant river channel with a poor connection to the mainstem.	Reconnect abandoned side channel between RM 4 and 5.6 to provide high flow refuge and rearing habitat for fish.
26	Dips Road Setback	West Valley Road (located at the "Dips") acts as a physical barrier to riparian habitat connectivity.	Relocate a small area of West Valley Road in the vicinity of the Dips to provide additional floodplain habitat and reduce the stranding potential for fish.
28	River Mile 9 Setback Levee	The connection to riparian habitats is restricted by a levee near the mainstem bank.	Construct setback levee near RM 7.5-8 to provide additional floodplain habitat and to reduce the stranding potential for fish. Breach existing levee at four locations to allow flood waters to flow freely within the levee setback area, providing salmon access to the riparian habitat.
35	Upstream LWD Installation	Spawning, rearing, and refuge habitats (including pools) are limited in RM 9 to 11 due to a lack of large woody debris in the upstream reaches of the Skokomish River.	Place and install large woody debris from RM 9-11 to increase meandering and bar formation and provide cover for salmon.
37	Grange Levee Setback	The connection to riparian habitats is restricted by the Grange Levee near the mainstem bank.	Construct setback levee near RM 8.3-9.2 to provide additional floodplain habitat and to reduce the stranding potential for fish. Breach existing levee at two locations to allow flood waters to flow freely within the levee setback area, providing salmon access to the riparian habitat.
39	Hunter Creek Mouth Restoration	There is a poor connection between the mouth of Hunter Creek and the mainstem.	Small-scale excavation at the mouth of Hunter Creek to provide year-round access between the Creek and mainstem river in the vicinity of RM 6.5.
40	Hunter Creek Tributary Restoration	Fish stranding commonly occurs at this site due to limited side channels off of Hunter Creek; spawning and rearing opportunities are significantly limited in Hunter Creek.	Construct tributary channels to Hunter Creek to provide additional fish rearing and refuge habitat.
43	Weaver Creek Tributary Restoration	A lack of juvenile salmonid rearing habitat & stranded fish during high flow events.	Construct tributary channels to Weaver Creek to provide additional fish rearing and refuge habitat.



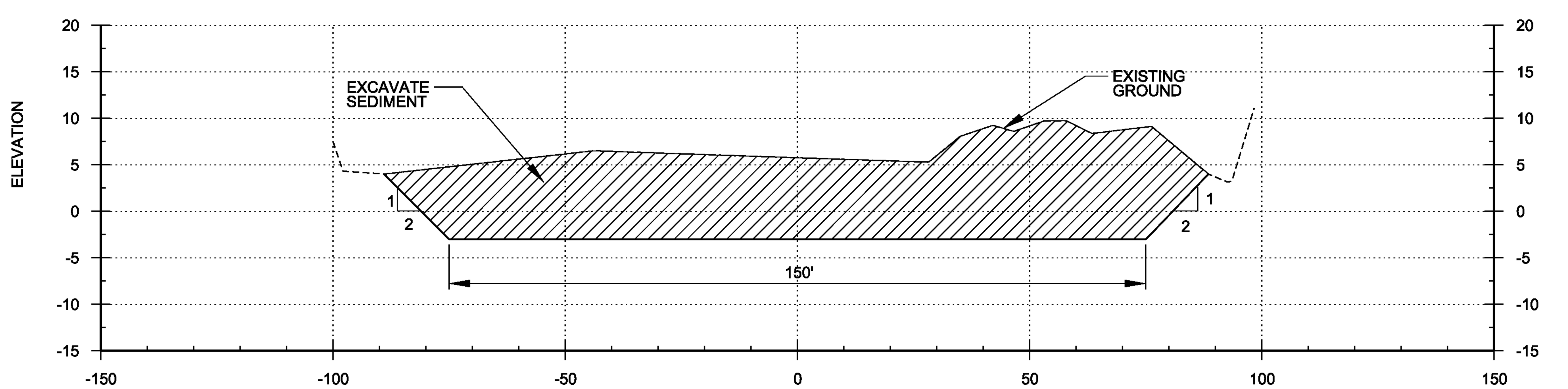
Orthophoto: 4/23/2011

Base 1 & 5 Calculations

BASE 1: DREDGE RIVER FROM RM 0-9.
BASE 5: DREDGE RIVER FROM RM 3-5



RM 6.0 - 9.0



RM 0 - 4.7

SEDIMENT REMOVAL TYPICAL SECTIONS
FOR ALTERNATIVES 1 & 5

ALTERNATIVE 1 RM 0 - 9.0
ALTERNATIVE 5 RM 3.5 - 9.0

SEDIMENT REMOVAL ESTIMATED QUANTITIES

ALTERNATIVE 1 RM 0 - 9.0 2,684,000 CY
ALTERNATIVE 5 RM 3.5 - 9.0 1,870,000 CY

HORIZ SCALE IN FEET
0 10' 20' 40'
0 5' 10' 20'
VERT. SCALE IN FEET
VERT. EXAGGERATION x 2

US Army Corps
of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:		DATE:
DWN BY:	CKD BY:	SOLICITATION NO.: X000XX-00-X-0002
SUBMITTED BY:		CONTRACT NO.: X000XX-00X-0000
PLOT DATE: 11/30/2012	PLOT TIME: 2:32:01 PM	FILE NUMBER: E-25-1-22
SIZE: ANSI D	FILE NAME:	

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832

SHEET
IDENTIFICATION

SHEET OF

DATE AND TIME PLOTTED: $$$DATE$$$$

DESIGN FILE: c:\users\g3ecdrd9\documents\cenws01\dms73333\PN60344_SKOK-C-301Alt1_vert_ex .DGN

End Area Program

Skokomish Dredge Volume Estimate RM 0-9

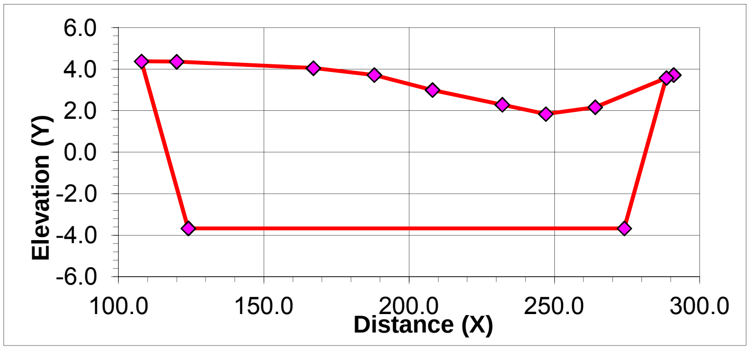
Station : RM 0.5

End Area = 1143.667

X	Y	X1*Y2	Y1*X2
120	4	486	728.12
167	4	621.24	761.4
188	4	564	773.76
208	3	476.32	696
232	2	426.88	565.63
247	2	535.99	485.76
264	2	982.08	631.47
291	4	1082.52	1082.52
291	3.72	1041.78	1073.183
288.49	3.58	-1058.76	980.92
274	-4	-1005.58	-455.08
124	-4	543.12	-395.956
107.89	4	470.4004	525.6
120	4	0	0
		5165.992	7453.327

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.



Assume typical cross section at RM 0.5*5 Miles [CY]~ 1,118,252

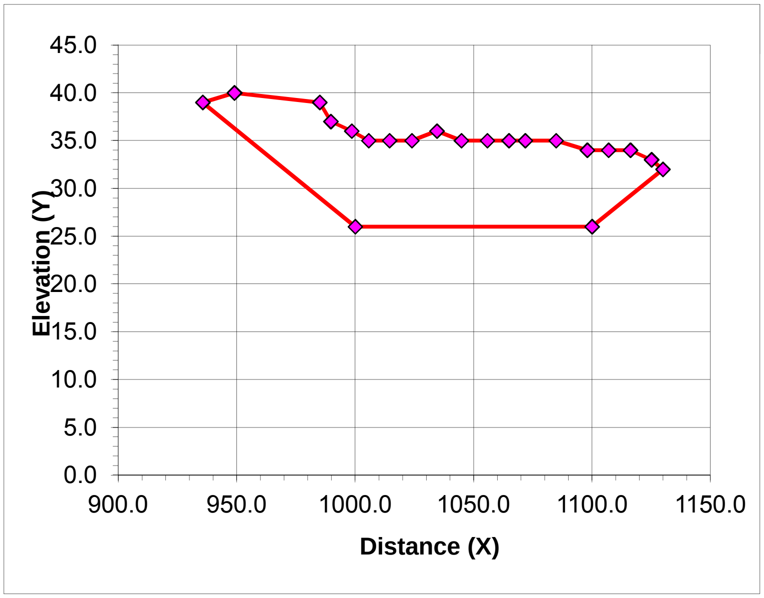
Station : RM 6.4

End Area = 1453.69

X	Y	X1*Y2	Y1*X2
949	40	37011	39400
985	39	36445	38598.3
989.7	37	35629.2	36944.5
998.5	36	34947.5	36205.2
1005.7	35	35199.5	35507.5
1014.5	35	35507.5	35836.5
1023.9	35	36860.4	36207.5
1034.5	36	36207.5	37612.8
1044.8	35	36568	36953
1055.8	35	36953	37271.5
1064.9	35	37271.5	37513
1071.8	35	37513	37968
1084.8	35	36883.2	38430
1098	34	37332	37638
1107	34	37638	37950.8
1116.2	34	36834.6	38253.4
1125.1	33	36003.2	37286.7
1129.9	32	29377.4	35200
1100	26	28600	26000
1000	26	39000	24326.38
935.63	39	37425.2	37011
949	40	0	0
		755206.7	758114.1

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.



Assume typical cross section at RM 6.4*RM (5.0-9.0) 4 Miles [CY]~ 1,137,109
Sum Typical Section Volumes CY 2,255,361
% difference from Ras Volume 16%
Use conservative volume generated from H&H RAS Model [CY]~ 2,684,000

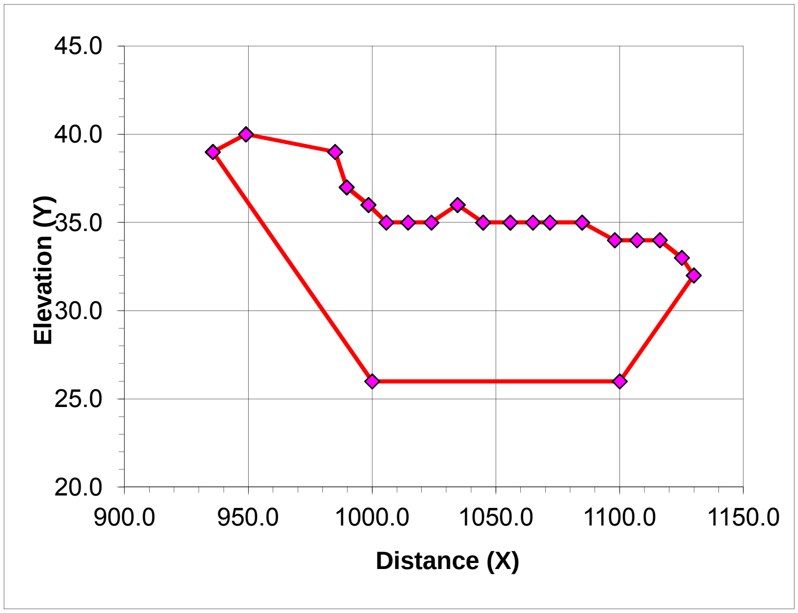
End Area Program

Skokomish Dredge Volume Estimate RM 3.5-9

Station : RM 6.4					End Area =	1453.69
X	Y	X1*Y2	Y1*X2			
949	40	37011	39400			
985	39	36445	38598.3			
989.7	37	35629.2	36944.5			
998.5	36	34947.5	36205.2			
1005.7	35	35199.5	35507.5			
1014.5	35	35507.5	35836.5			
1023.9	35	36860.4	36207.5			
1034.5	36	36207.5	37612.8			
1044.8	35	36568	36953			
1055.8	35	36953	37271.5			
1064.9	35	37271.5	37513			
1071.8	35	37513	37968			
1084.8	35	36883.2	38430			
1098	34	37332	37638			
1107	34	37638	37950.8			
1116.2	34	36834.6	38253.4			
1125.1	33	36003.2	37286.7			
1129.9	32	29377.4	35200			
1100	26	28600	26000			
1000	26	39000	24326.38			
935.63	39	37425.2	37011			
949	40	0	0			
		755206.7	758114.1			

* Remember to reenter the 1st X1/Y1 as the last entry.

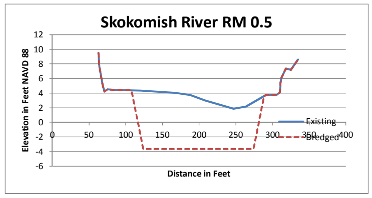
* If you have more than 16 X/Y entries just add some rows above Row 20.



Assume typical cross section at RM 6.4*RM (3.5-9.0) 5.5 Miles [CY]~ 1,563,524
% difference from Ras Volume 16%
Use conservative volume generated from H&H RAS Model [CY]~ 1,870,000

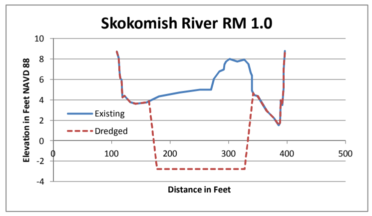
SKOKOMISH RIVER DREDGING RM 0-9

Feet from LB	Elev in Feet	Feet from LB	Elev in Feet
63	10	63	10
64	8	64	8
69	5	69	5
71	4	71	4
75	5	75	5
85	4	85	4
120	4	107.89	4
167	4	124	-4
188	4	274	-4
208	3	288.49	3.58
232	2	291	3.72
247	2	306	3.79
264	2	310	4.1
291	4	311	4.91
306	4	311	5.38
310	4	312	6.1
311	5	318	7.34
311	5	325	7.17
312	6	335	8.58
318	7		
325	7		
335	9		



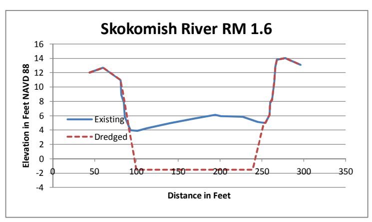
Survey Width		Excav
272		272
Dredge Top Width		
180.6		
Bottom width	150	
slope	0.500345	2.00

X-Sec 1.0 Existing		X-Sec 1.0 Dredged	
Feet from LB	Elev in Feet	Feet from LB	Elev in Feet
109	9	109	9
112	8	112	8
114	7	114	7
115	6	115	6
117	6	117	6
118	5	118	5
119	4	119	4
122	4	122	4
132	4	132	4
141	4	141	4
160	4	160	4
181	4	164.22	4
216	5	177.5	-3
251	5	327.5	-3
270	5	342.35	5
275	6	344	4
284	7	350	4
292	7	365	3
293	7	378	2
296	8	386	2
302	8	388	2
315	8	389	4
327	8	392	4
334	7	394	5
338	7	394	7
340	6	396	9
340	5		
344	4		
350	4		
365	3		
378	2		
386	2		
388	2		
389	4		
392	4		
394	5		
394	7		
396	9		



Survey Width		Excav
Dredge Top Width		
178.13		
Bottom width	150	
slope	0.499663	2.00

X-Sec 1.6 Existing		X-Sec 1.6 Dredged	
Feet from LB	Elev in Feet	Feet from LB	Elev in Feet
44	12	44	12
60	13	60	12.69
81	11	81	11
82	9	100	-1.54
85	8	239	-1.54
86	6	252.11	5.01
93	4	254	4.99
101	4	259	6.12
112	4	260	7.82
140	5	262	8.27
170	6	265	10.78
194	6	266	12.8
201	6	268	13.8
227	6	278	14.02
245	5	296	13.09
250	5		
254	5		
259	6		
260	8		
262	8		
265	11		
266	13		
268	14		
278	14		
296	13		



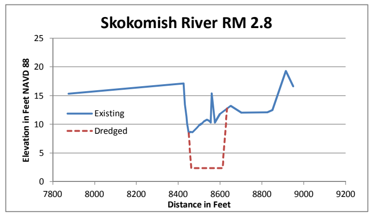
Survey Width		Excav
252		
Dredge Top Width		
171.11		
Bottom width	139	
slope	0.499619	2.0

X-Sec 16 Existing

Feet from LB	Elev in Feet
7875	15
8425	17
8432.2	14
8439.2	11
8441.8	10
8450.4	8
8458.5	9
8468.2	9
8478.9	9
8489.1	9
8500.4	10
8512.1	10
8523.5	11
8537.1	11
8546	11
8555.1	10
8556	11
8556.8	12
8560.4	15
8575	10
8600	12
8650	13
8700	12
8825	12
8850	13
8915	19
8950	17

X-Sec 16 Dredged

Feet from LB	Elev in Feet
8450.24	8
8462.5	2
8612.5	2
8633.28	13



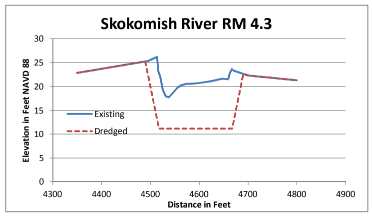
Survey Width		Excav
	1075	
Dredge Top Width		
	183.04	
Bottom width	150	
slope	0.5	2.0

X-Sec 22 Existing

Feet from LB	Elev in Feet
4350	23
4495	25
4514	26
4516.4	23
4520.4	22
4525.6	19
4531.6	18
4538.2	18
4546.3	19
4555.4	20
4565	20
4573.8	21
4584.5	21
4595.7	21
4606.9	21
4616.7	21
4626.1	21
4638.3	21
4648.2	22
4658.8	21
4661.2	22
4662.5	23
4666.6	24
4671	23
4700	22
4800	21

X-Sec 22 Dredged

Feet from LB	Elev in Feet
4350	23
4489.37	25
4517.5	11
4667.5	11
4690.48	23
4700	22
4800	21



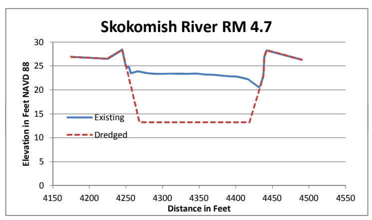
Survey Width		Excav
	450	
Dredge Top Width		
	201.11	
Bottom width	150	
slope	0.5	2.0

X-Sec 24 Existing

Feet from LB	Elev in Feet
4175	27
4225	27
4245	28
4249.8	25
4253.9	25
4256.8	24
4266.3	24
4276.9	24
4288.3	23
4299.8	23
4310.2	23
4321.7	23
4333.5	23
4346.3	23
4357.4	23
4370.1	23
4382.7	23
4393.8	23
4400	23
4406.3	23
4416.9	22
4425.1	21
4431.8	21
4433.6	21
4437.6	23
4438.2	24
4438.7	27
4442	28
4490	26

X-Sec 24 Dredged

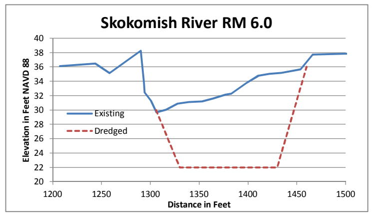
Feet from LB	Elev in Feet
4175	27
4225	27
4245	28
4268.5	13
4418.5	13
4436.77	22
4437.6	23
4438.2	24
4438.7	27
4442	28
4490	26



Survey Width		Excav
	315	
Dredge Top Width		
	191.77	
Bottom width	150	
slope	0.499726	2.0

X-Sec 37 Existing	
Feet from LB	Elev in Feet
1207.24	36
1243.44	36
1257.96	35
1290	38
1293.3	34
1294.1	32
1300.6	31
1306.2	30
1316.1	30
1327.7	31
1339.4	31
1353	31
1364.3	32
1376.8	32
1382.9	32
1398.1	34
1410.5	35
1422	35
1434.3	35
1447	35
1453.9	36
1466.2	38
1600	38
1604.9	36
1610.7	35
1620.7	35
1628.9	34
1639.1	35
1645.8	34
1651.2	33
1661.2	31
1671.5	30
1681.1	29
1686.8	29
1690.5	30
1690.7	32
1691	35
1691.8	37
1730.02	35
1905.51	36

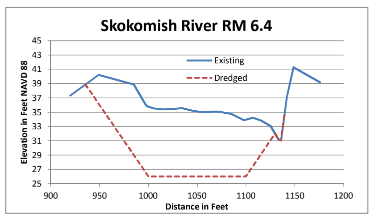
X-Sec 37 Dredged	
Feet from LB	Elev in Feet
1306	30
1330	22
1430	22
1460	36



	Survey Width			Excav
		698.27		
	Dredge Top Width			
		154		
	Bottom width		100	
rt	slope		0.466667	2.1
lt	slope		-0.33333	-3.0

X-Sec 40 Existing	
Feet from LB	Elev in Feet
919.69	37
949	40
985	39
989.7	38
994.1	37
998.5	36
1005.7	35
1014.5	35
1023.9	35
1034.5	36
1044.8	35
1055.8	35
1064.9	35
1071.8	35
1084.8	35
1098	34
1107	34
1116.2	34
1125.1	33
1133.3	31
1136	31
1139.8	35
1141.8	37
1148.7	41
1176	39

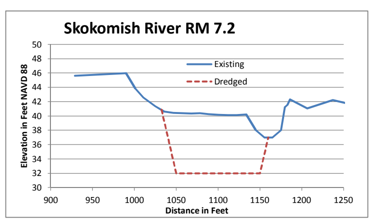
X-Sec 40 Dredged	
Feet from LB	Elev in Feet
935.63	39
1000	26
1100	26
1129.86	32
1133.3	31
1136	31
1139.8	35



	Survey Width			Excav
		256.31		204.17
	Dredge Top Width			
		194.23		
	Bottom width		100	
rt	slope		0.199933	5.0
lt	slope		-0.19994	-5.0

X-Sec 44 Existing	
Feet from LB	Elev in Feet
928.84	46
990	46
1000.9	44
1010.8	43
1024.7	41
1035.9	41
1046.6	40
1057.7	40
1068	40
1078.3	40
1088.6	40
1100.4	40
1111.9	40
1122.3	40
1133.7	40
1144.9	38
1155.3	37
1165.1	37
1175.1	38
1180	41
1182.9	42
1185.8	42
1206.42	41
1237.12	42
1253.45	42

X-Sec 44 Dredged	
Feet from LB	Elev in Feet
1032.28	41
1050	32
1150	32
1160	37



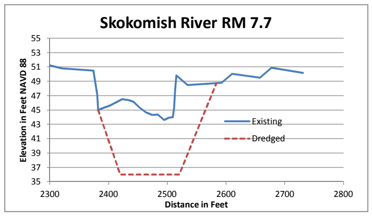
	Survey Width			Excav
		324.61		
	Bottom width		100	
rt	slope		0.5	2.0
lt	slope		-0.5	-2.0
	Dredge Top Width			
		127.72		

X-Sec 47 Existing

Feet from LB	Elev in Feet
2298.17	51
2320.33	51
2374	50
2380.6	47
2382.1	45
2389.7	45
2400.6	46
2412.6	46
2423	46
2434.2	46
2442.1	46
2453.2	45
2463.5	45
2473.9	44
2483.8	44
2494.6	44
2502.3	44
2509.2	44
2511.3	45
2513	48
2515.4	50
2534.36	48
2592.17	49
2610.21	50
2657.77	50
2677.16	51
2730.9	50

X-Sec 47 Dredged

Feet from LB	Elev in Feet
2382.1	45
2420	36
2520	36
2583.58	49



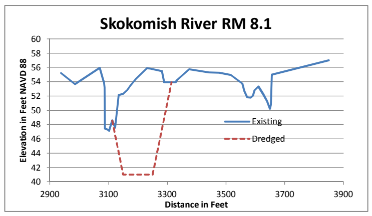
	Survey Width		
		432.73	
	Dredge Top Width		
		201.48	
	Bottom width	100	
rt	slope	0.200063	5.0
lt	slope	-0.23642	-4.2

X-Sec 51 Existing

Feet from LB	Elev in Feet
2938.2	55
2985.91	54
3070	56
3082.2	54
3084.5	54
3086.6	53
3087.8	47
3095.9	47
3101.6	47
3112.8	49
3122.2	48
3134.1	52
3149.1	52
3163.7	53
3173.8	53
3193.2	54
3230.3	56
3240.7	56
3281.6	55
3288.9	54
3328.3	54
3333.3	54
3373.8	56
3442.2	55
3476.9	55
3515.8	55
3555.1	54
3562.5	53
3572.4	52
3583.4	52
3591.8	52
3597.3	53
3610.5	53
3626.2	52
3639.5	51
3649.6	50
3652.4	51
3655.7	55
3850	57

X-Sec 51 Dredged

Feet from LB	Elev in Feet
3112.29	49
3150	41
3250	41
3314.63	54



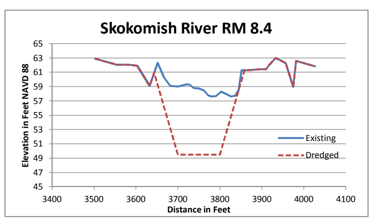
	Survey Width		
		911.8	
	Dredge Top Width		
		202.34	
	Bottom width	100	
rt	slope	0.200062	5.0
lt	slope	-0.19995	-5.0

X-Sec 55 w/o Dredging

3502.4	63
3553.7	62
3581.8	62
3602.9	62
3632.3	59
3651.3	62
3666.5	60
3681.2	59
3700.8	59
3721.4	59
3727.2	59
3738.3	59
3749.6	59
3761.4	58
3772.5	58
3779.6	58
3790.4	58
3802.8	58
3815.7	58
3826	58
3836.1	58
3844.7	59
3846.9	60
3851.5	61
3869.5	61
3893.4	61
3910	61
3916.6	62
3932.8	63
3948.6	63
3957.5	62
3974.4	59
3981.7	63
4026.96	62

X-Sec 55 w/Dredging

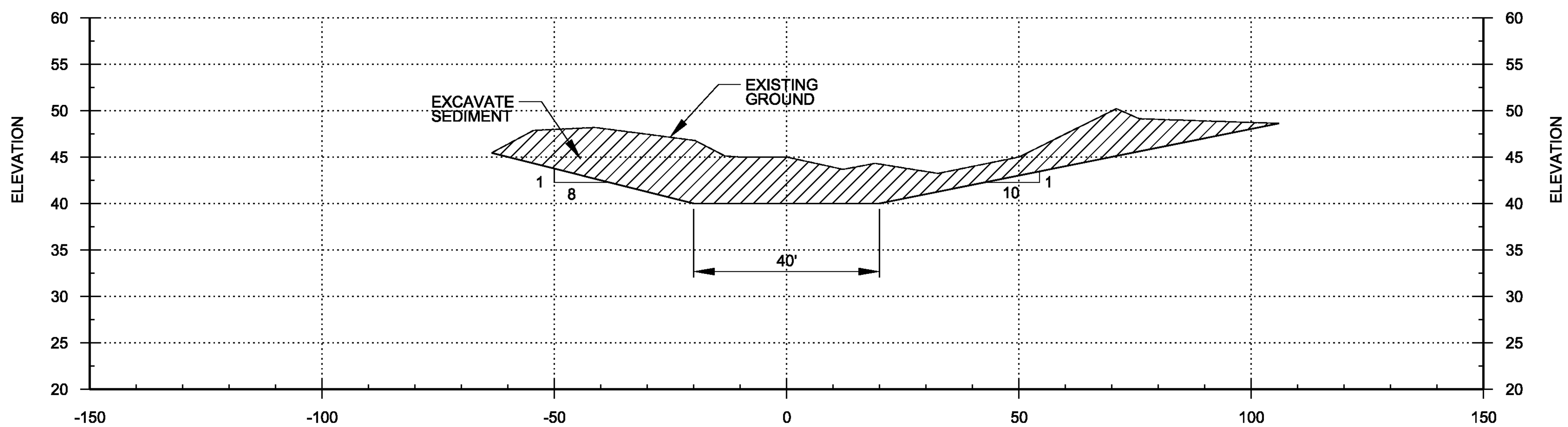
3502.4	63
3553.7	62
3581.8	62
3602.9	62
3632.3	59
3642.97	61
3700	50
3800	50
3858.89	61
3869.5	61
3893.4	61
3910	61
3916.6	62
3932.8	63
3948.6	63
3957.5	62
3974.4	59
3981.7	63
4026.96	62



	Survey Width		
		524.56	
	Dredge Top Width		
		215.92	
	Bottom width	100	
rt	slope	0.200034	5.0
lt	slope	-0.20007	-5.0

Base 2 Calculations

BASE 2: CONFLUENCE DREDGING



DISTANCE IN FEET

RM 7.3-8.8

SEDIMENT REMOVAL TYPICAL SECTION

ALTERNATIVE 2

NOTES:

ALTERNATIVE 2 SEDIMENT REMOVAL
ESTIMATED VOLUME 150,000 CY

HORIZ SCALE IN FEET

0 10' 20' 40'

0 5' 10' 20'

VERT. SCALE IN FEET

VERT. EXAGGERATION x 2

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY:		DATE:
DWN BY:	CKD BY:	SOLICITATION NO.: X000XX-00-X-0002
SUBMITTED BY:		CONTRACT NO.: X000XX-00X-0000
PLOT DATE: 4/10/2013	PLOT TIME: 1:49:07 PM	FILE NUMBER: E-25-1-22
SIZE: ANSI D	FILE NAME:	

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832

SHEET IDENTIFICATION

SHEET OF

DATE AND TIME PLOTTED: $$$DATE$$$$

DESIGN FILE: c:\users\g3ecdrd9\documents\cenws01\dms73333\PN60344_SKOK-C-301Alt2_vert_ex.DGN

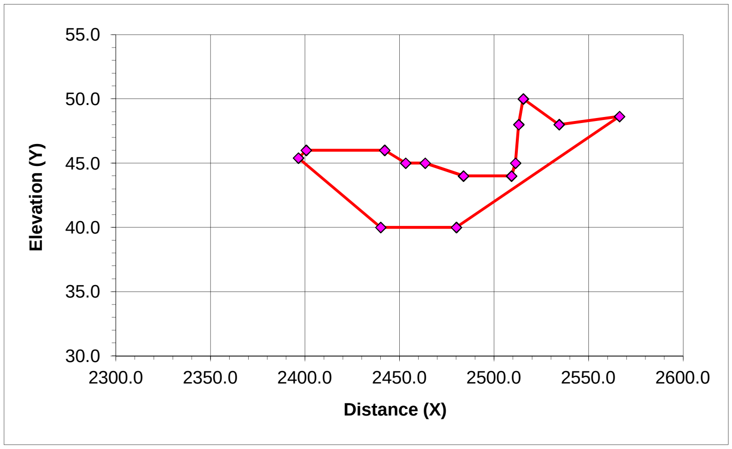
Skokomish Dredge Volume Estimate RM 7.3-8.8 Base 2

Station : 7.7 | **End Area =** 566.3566

X	Y	X1*Y2	Y1*X2
2396.5	45.4	110239	108987.2
2400.6	46	110427.6	112336.6
2442.1	46	109894.5	112847.2
2453.2	45	110394	110857.5
2463.5	45	108394	111771
2483.8	44	109287.2	110404.8
2509.2	44	112914	110497.2
2511.3	45	120542.4	113085
2513	48	125650	120739.2
2515.4	50	120739.2	126718
2534.36	48	123245.9	123182.4
2566.3	48.63	102652	120602.4
2480	40	99200	97600
2440	40	110776	95860
2396.5	45.4	0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		1574356	1575489

***** Remember to reenter the 1st X1/Y1 as the last entry.

***** If you have more than 16 X/Y entries just add some rows above Row 20.



Assume typical cross section at RM 7.7 for RM 7.3-8.3 (1.0 Miles) [CY]~ 110,754

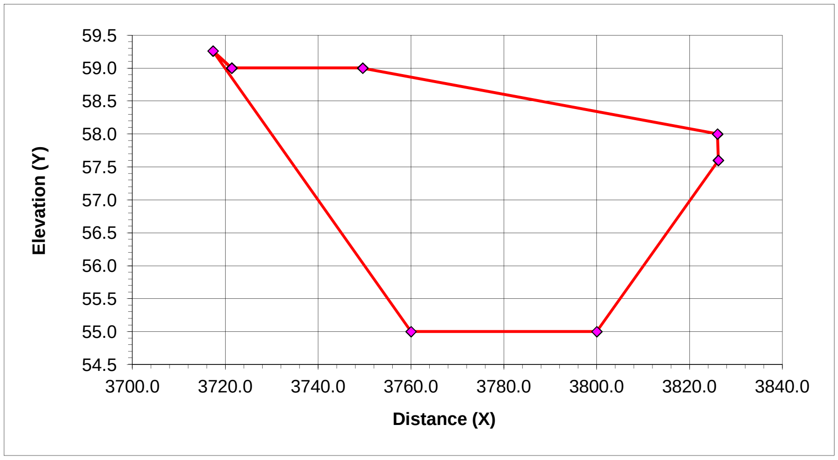
Run # :

Station : 8.4 | **End Area =** 272.517

X	Y	X1*Y2	Y1*X2
3721.4	59	219562.6	221226.4
3749.6	59	217476.8	225734
3826	58	220377.6	221917.9
3826.17	58	210439.4	218880
3800	55	209000	206800
3760	55	222817.6	204454.8
3717.36	59.26	219324.2	220530.2
3721.4	59	0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		1518998	1519543

***** Remember to reenter the 1st X1/Y1 as the last entry.

***** If you have more than 16 X/Y entries just add some rows above Row 20.



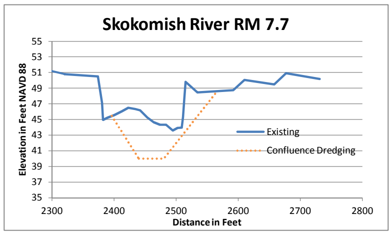
Assume typical cross section at RM 8.4 for RM 8.3-8.8 (0.5 Miles) [CY]~ 26,646
Sum Quantites from RM 7.7 & 8.4 CY 137,400
% difference from Ras Volume 8%
Use conservative volume generated from H&H RAS Model [CY 150,000

X-Sec 47 Existing

Feet from LB	Elev in Feet
2298.17	51
2320.33	51
2374	50
2380.6	47
2382.1	45
2389.7	45
2400.6	46
2412.6	46
2423	46
2434.2	46
2442.1	46
2453.2	45
2463.5	45
2473.9	44
2483.8	44
2494.6	44
2502.3	44
2509.2	44
2511.3	45
2513	48
2515.4	50
2534.36	48
2592.17	49
2610.21	50
2657.77	50
2677.16	51
2730.9	50

X-Sec 47 Confluence Dredging

Feet from L	Elev in Feet
2396.47	45.44
2440	40
2480	40
2566.3	48.63



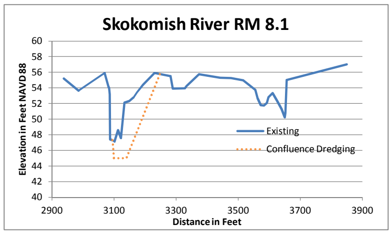
Dredge Top width	169.83	
		Approx ave Ex Depth
Bottom Width	40	5
left slope	-8	
right slope	10	

X-Sec 51 Existing

Feet from LB	Elev in Feet
2938.2	55
2985.91	54
3070	56
3082.2	54
3084.5	54
3086.6	53
3087.8	47
3095.9	47
3101.6	47
3112.8	49
3122.2	48
3134.1	52
3149.1	52
3163.7	53
3173.8	53
3193.2	54
3230.3	56
3240.7	56
3281.6	55
3288.9	54
3328.3	54
3333.3	54
3373.8	56
3442.2	55
3476.9	55
3515.8	55
3555.1	54
3562.5	53
3572.4	52
3583.4	52
3591.8	52
3597.3	53
3610.5	53
3626.2	52
3639.5	51
3649.6	50
3652.4	51
3655.7	55
3850	57

X-Sec 51 Confluence Dredging

Feet from L	Elev in Feet
3095.38	47.31
3100	45
3140	45
3247.79	55.78



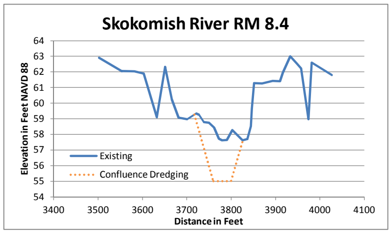
Dredge Top width	152.41	
		Approx ave Ex Depth
Bottom Width	40	6
left slope	-2	
right slope	9.999072356	

X-Sec 55 w/o Dredging

3502.4	63
3553.7	62
3581.8	62
3602.9	62
3632.3	59
3651.3	62
3666.5	60
3681.2	59
3700.8	59
3721.4	59
3727.2	59
3738.3	59
3749.6	59
3761.4	58
3772.5	58
3779.6	58
3790.4	58
3802.8	58
3815.7	58
3826	58
3836.1	58
3844.7	59
3846.9	60
3851.5	61
3869.5	61
3893.4	61
3910	61
3916.6	62
3932.8	63
3948.6	63
3957.5	62
3974.4	59
3981.7	63
4026.96	62

X-Sec 55 Confluence Dredging

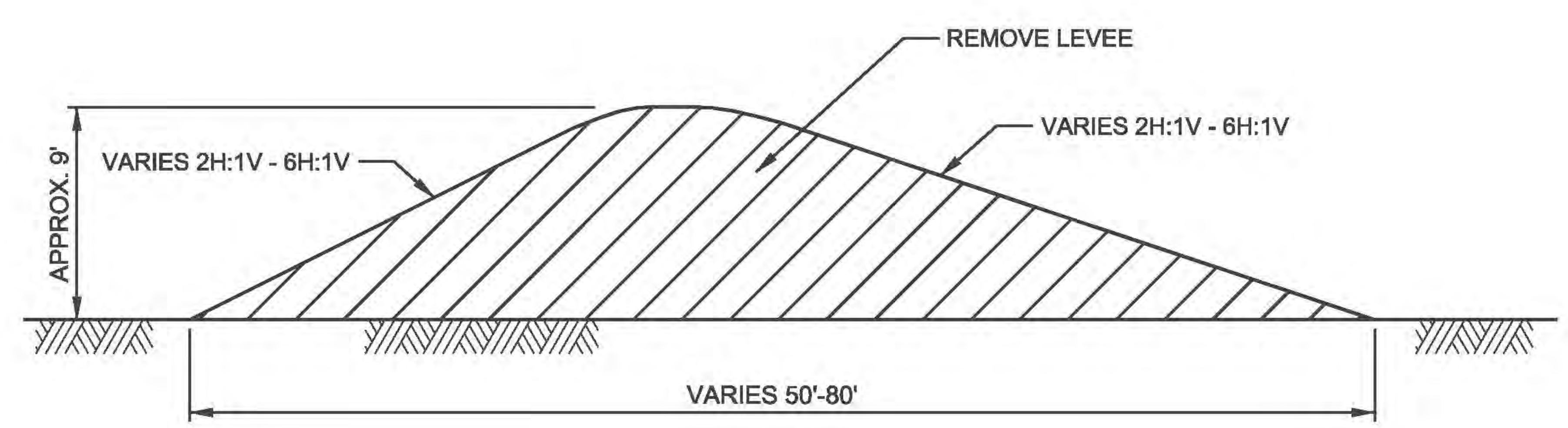
Feet from L	Elev in Feet
3717.36	59.26
3760	55
3800	55
3826.17	57.62



Dredge Top widt	108.81	
		Approx ave Ex Depth
Bottom Width	40	3
left slope	-10	
right slope	10	

Car Body Calculations

Levee Degrade



CAR BODY LEVEE DEGRADE
NOT TO SCALE

LEGEND	
(hatch)	REMOVE MATERIAL

VOLUME CY	LENGTH LF
23,196	4,592

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SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: MAY		DATE: DD MONTH 2011
DWN BY: RR	CKD BY:	SOLICITATION NO.: X000XX-00-X-0002
SUBMITTED BY:		CONTRACT NO.: X000XX-00X-0000
PLOT DATE: 4/17/2013	PLOT TIME: 3:31:30 PM	FILE NUMBER: E-25-1-22
SIZE: ANSI D	FILE NAME: PN60344_SKOK-C-CAR-BODY-LEVEE.DGN	

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832

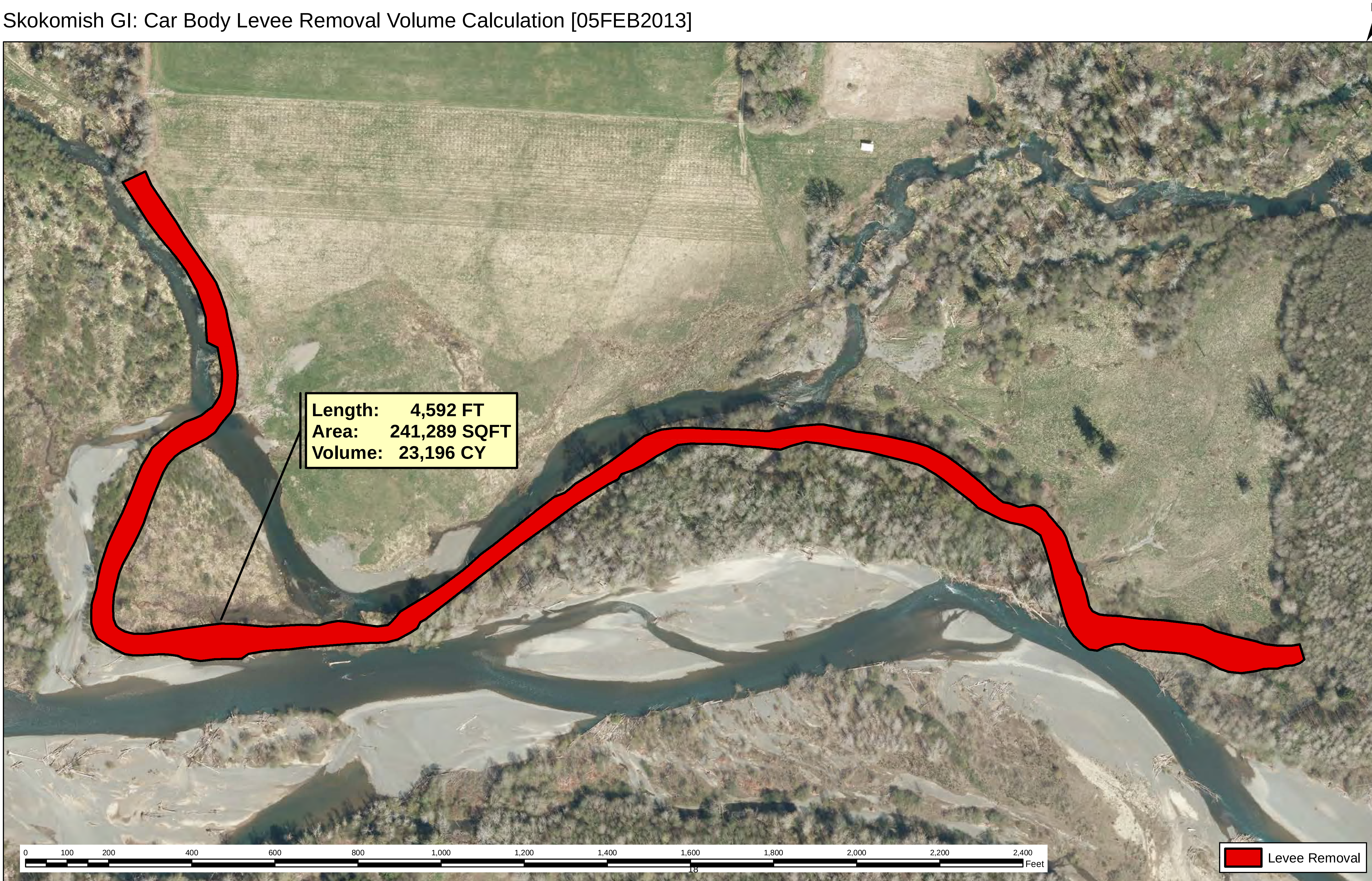
ALTERNATIVE 3

SHEET IDENTIFICATION
C-301
SHEET OF

DATE AND TIME PLOTTED: $$$DATE$$$$

DESIGN FILE: c:\users\g3ecdrd9\documents\cenws01\dms73333\PN60344_SKOK-C-CAR-BODY-LEVEE.DGN

Skokomish GI: Car Body Levee Removal Volume Calculation [05FEB2013]



Skokomish Volume Estimate Car Body Degrade

Car Body Levee Volume CY= 26,625

Percent Difference from GIS Calc 13% **End Area =** 148.65

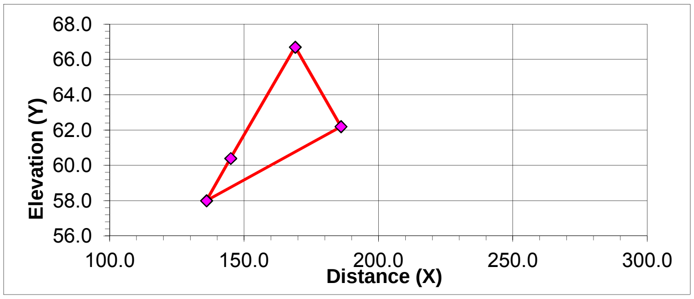
Linear Feet Car Body
616
65
957
1167
930
281
577
Sum **4593**

Section A LF 616

X	Y	X1*Y2	Y1*X2
136	58	8214.4	8410
145	60	9671.5	10207.6
169	67	10511.8	12406.2
186	62	10788	8459.2
136	58	0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		39185.7	39483

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.



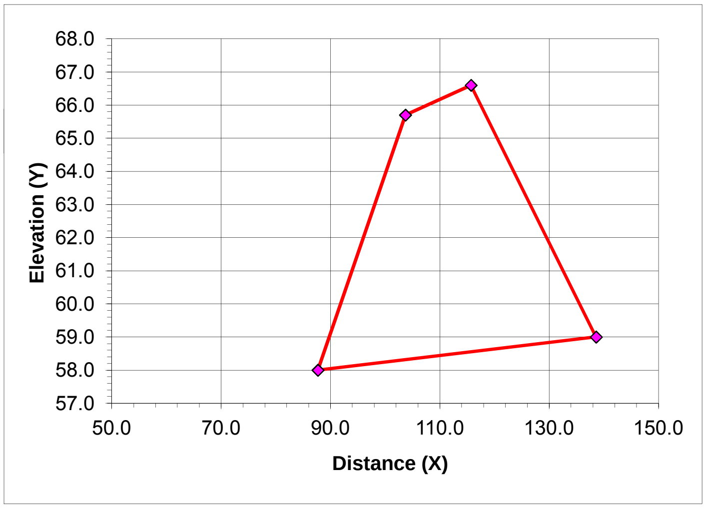
Assume typical cross section A at 0-616 Feet [CY]~ 3,391

Section C LF 1022 **End Area =** 243.87

X	Y	X1*Y2	Y1*X2
87.7	58	5761.89	6014.6
103.7	65.7	6906.42	7601.49
115.7	66.6	6826.3	9230.76
138.6	59	8038.8	5174.3
87.7	58	0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		27533.41	28021.15

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.

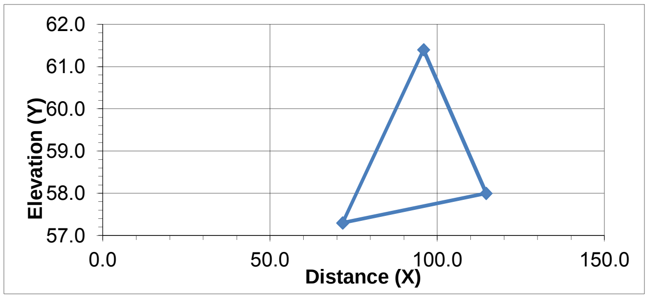


Assume typical cross section C 616-1638 feet [CY]~ 9,231

Run # :					End Area =	79.475
Section	D	LF	1822			
X	Y	X1*Y2	Y1*X2			
71.7	57.3	4402.38	5495.07			
95.9	61	5562.2	7036.44			
114.6	58	6566.58	4158.6			
71.7	57	0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		16531.16	16690.11			

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.

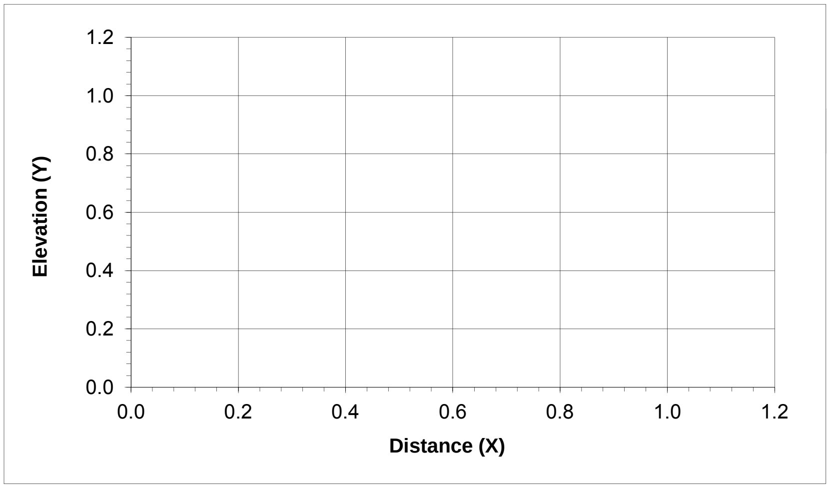


Assume typical cross section D 1638-2805 & 3080-3735 feet [CY 5,363

Breach Section No Degrading					End Area =	0
Section	E	LF	275			
X	Y	X1*Y2	Y1*X2			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			
		0	0			

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.



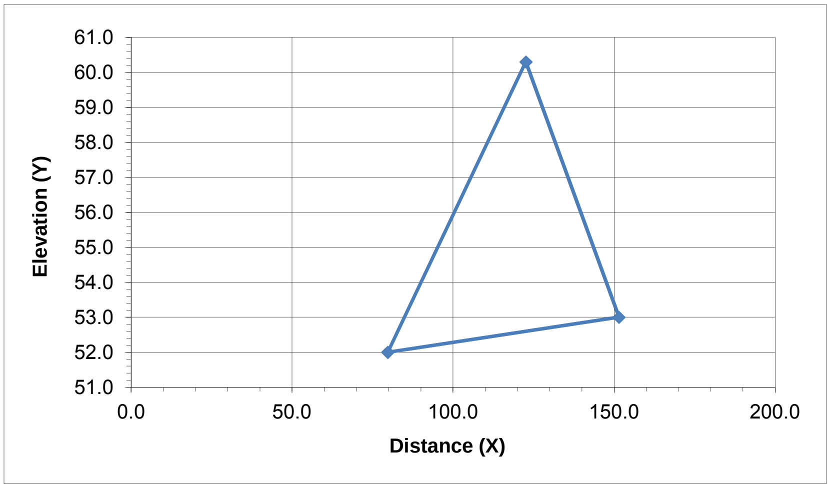
Assume Breach section E 2805-3080Ft= 275LF [CY]~ 0 0

Section	F	LF	281
Run # :			
Station :			
X	Y	X1*Y2	Y1*X2
79.7	52	4805.91	6375.2
122.6	60.3	6497.8	9135.45
151.5	53	7878	4224.1
79.7	52	0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		19181.71	19734.75

End Area = 276.52

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.



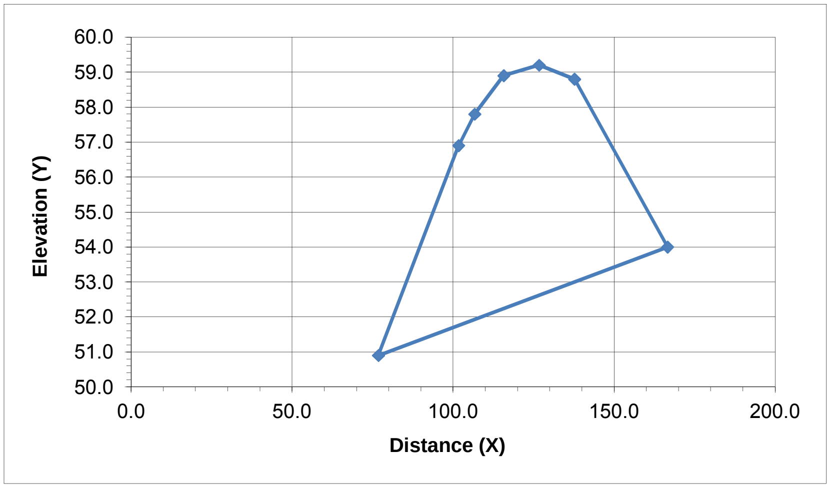
Assume typical cross section F 3735-4016 281 LF [CY]~ 2,878

Section	G	LF	273
Run # :			
Station :			
X	Y	X1*Y2	Y1*X2
76.8	50.9	4369.92	5176.53
101.7	56.9	5878.26	6071.23
106.7	57.8	6284.63	6687.46
115.7	58.9	6849.44	7462.63
126.7	59.2	7449.96	8151.84
137.7	58.8	7435.8	9796.08
166.6	54	8479.94	4147.2
76.8	50.9	0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		46747.95	47492.97

End Area = 372.51

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.



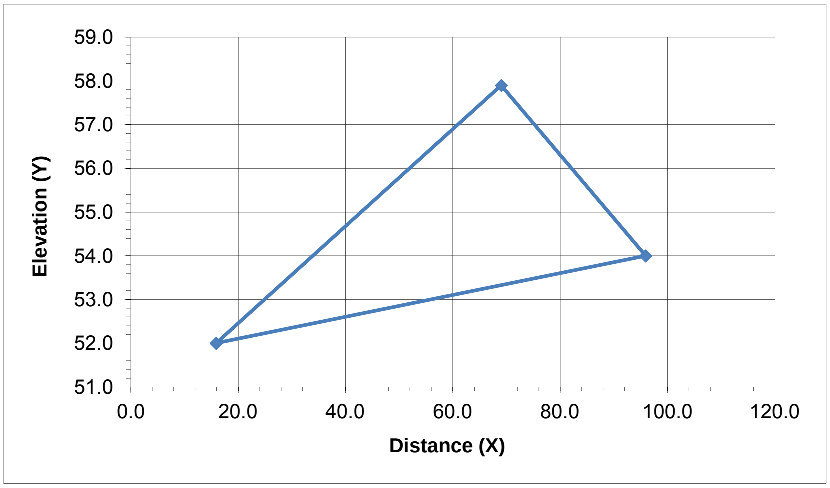
Assume typical cross section G 273 LF [CY]~ 3,766

Section	Gsmall1 LF		171
Run # :			
Station :			
X	Y	X1*Y2	Y1*X2
15.9	52	920.61	3588
69	57.9	3726	5552.61
95.9	54	4986.8	858.6
15.9	52	0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		9633.41	9999.21

End Area = 182.9

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.



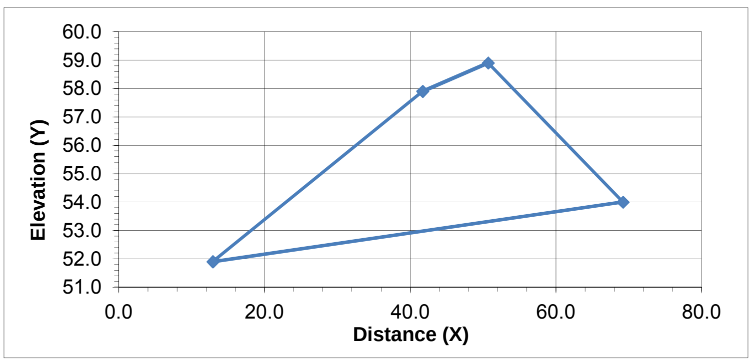
Assume typical cross section G 171 LF [CY]~ 1,158

Section	G Small LF		133
Run # :			
Station :			
X	Y	X1*Y2	Y1*X2
12.9	51.9	746.91	2164.23
41.7	57.9	2456.13	2935.53
50.7	58.9	2737.8	4075.88
69.2	54	3591.48	696.6
12.9	51.9	0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		9532.32	9872.24

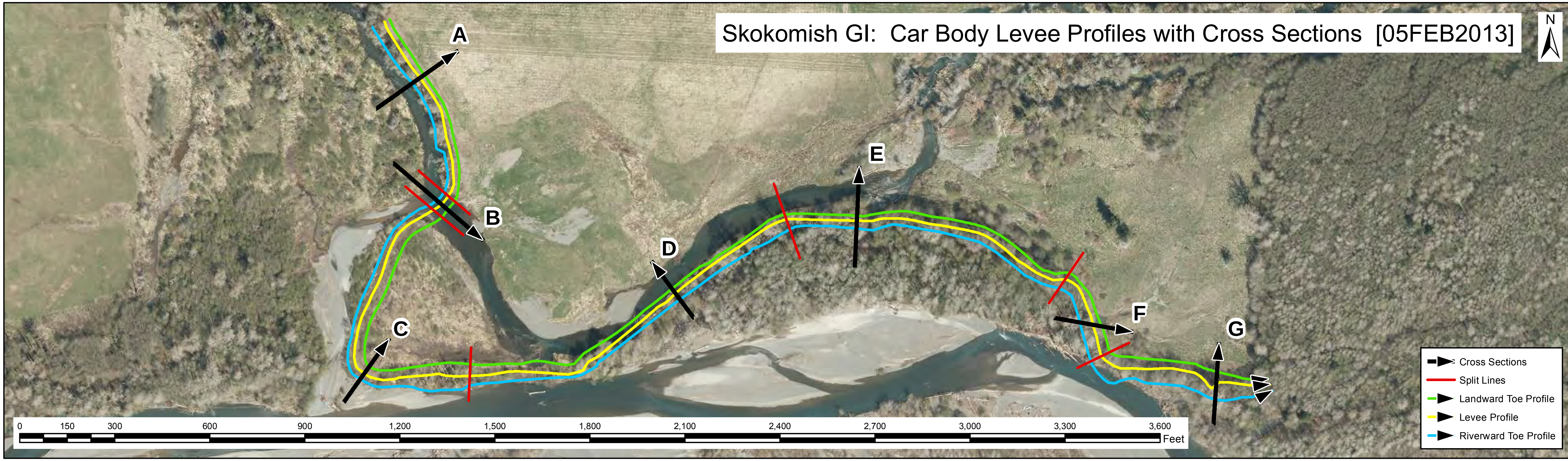
End Area = 169.96

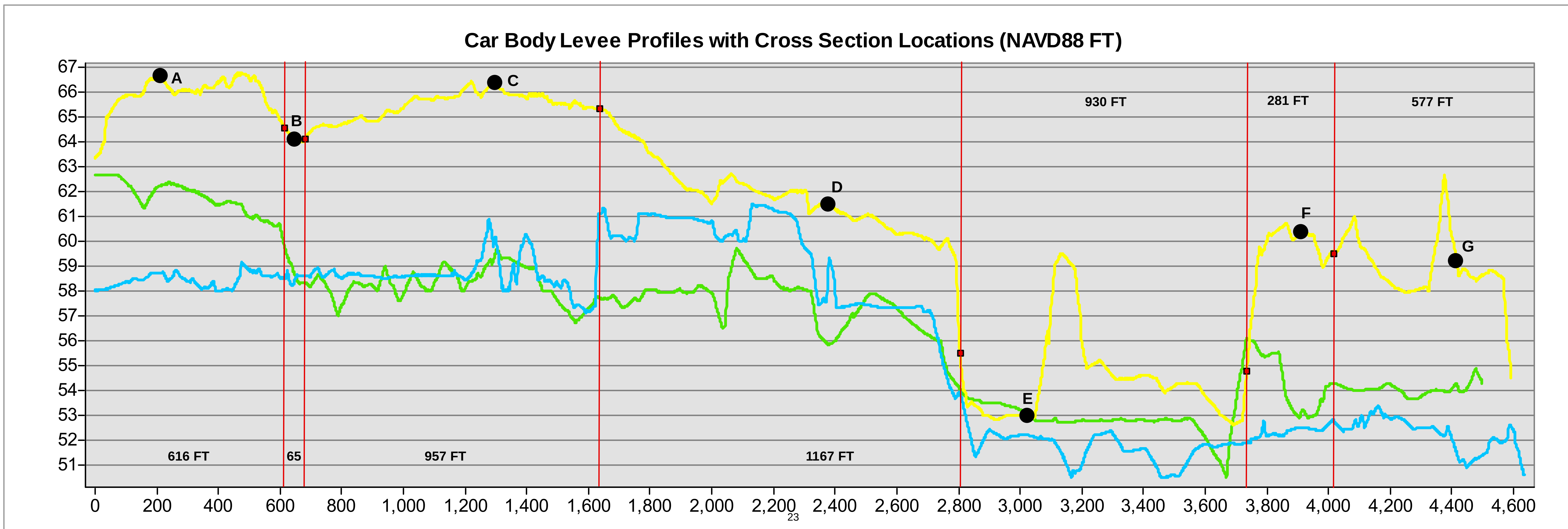
* Remember to reenter the 1st X1/Y1 as the last entry.

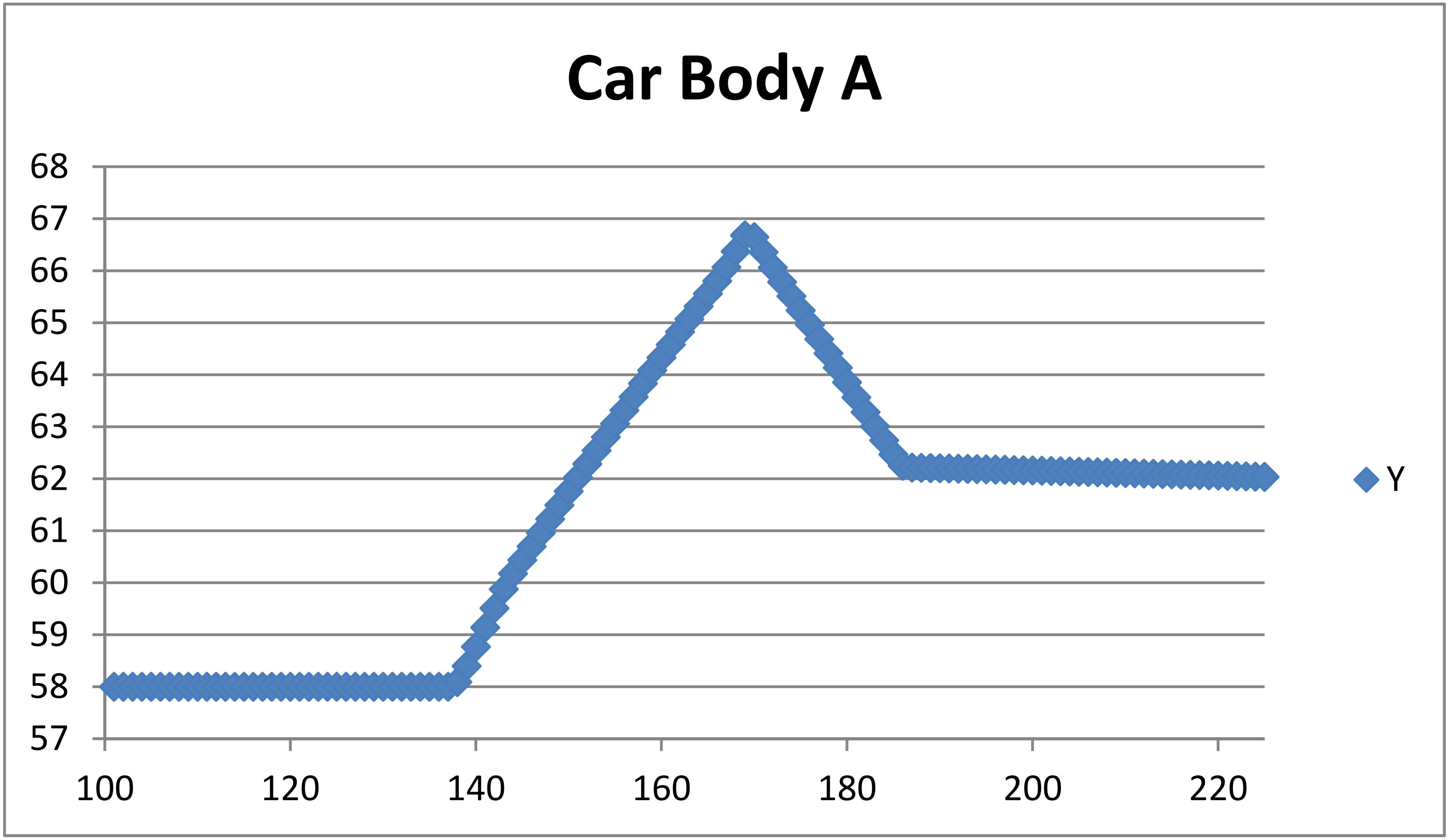
* If you have more than 16 X/Y entries just add some rows above Row 20.

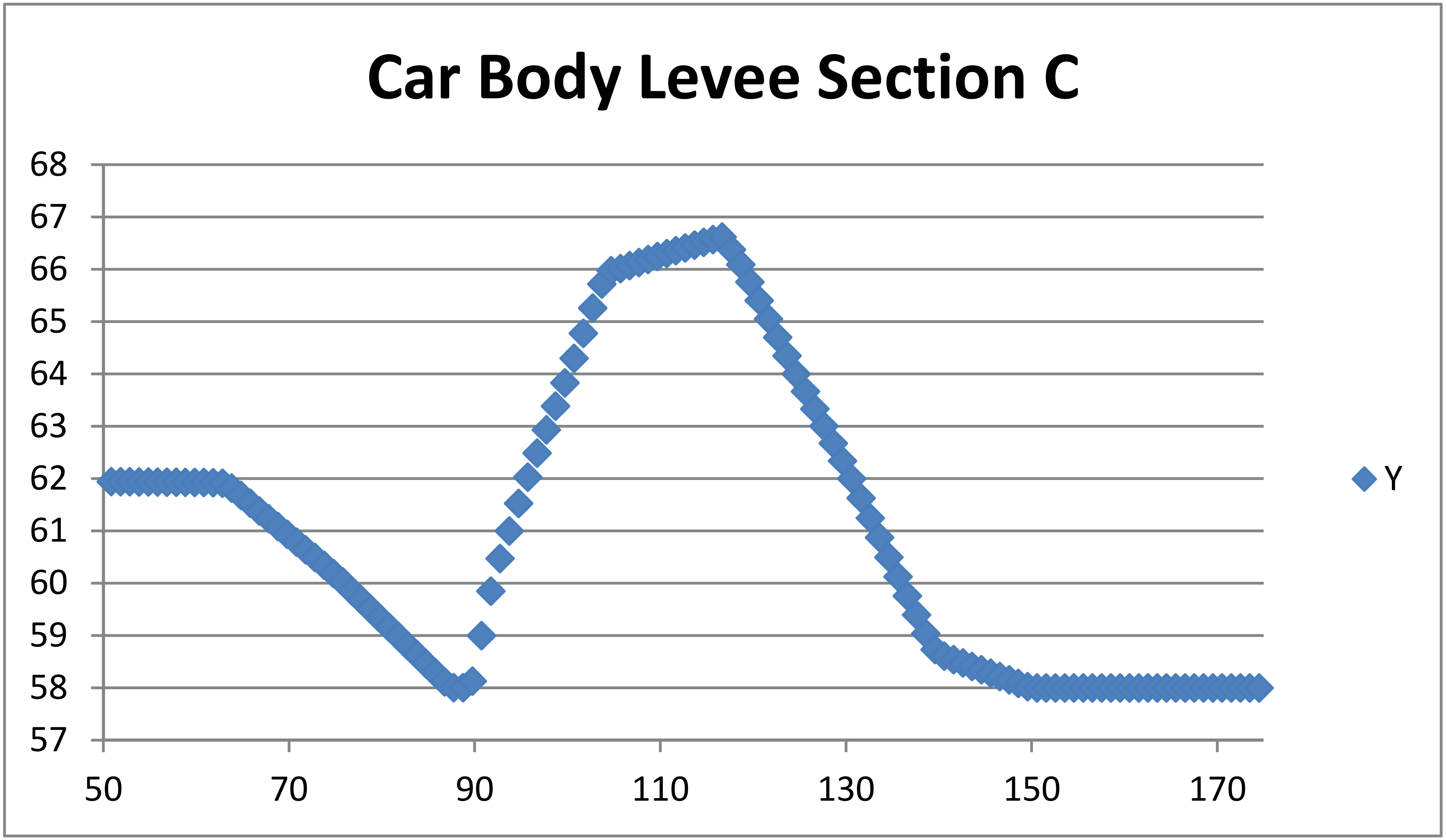


Assume typical cross section G 133 LF [CY]~ 837

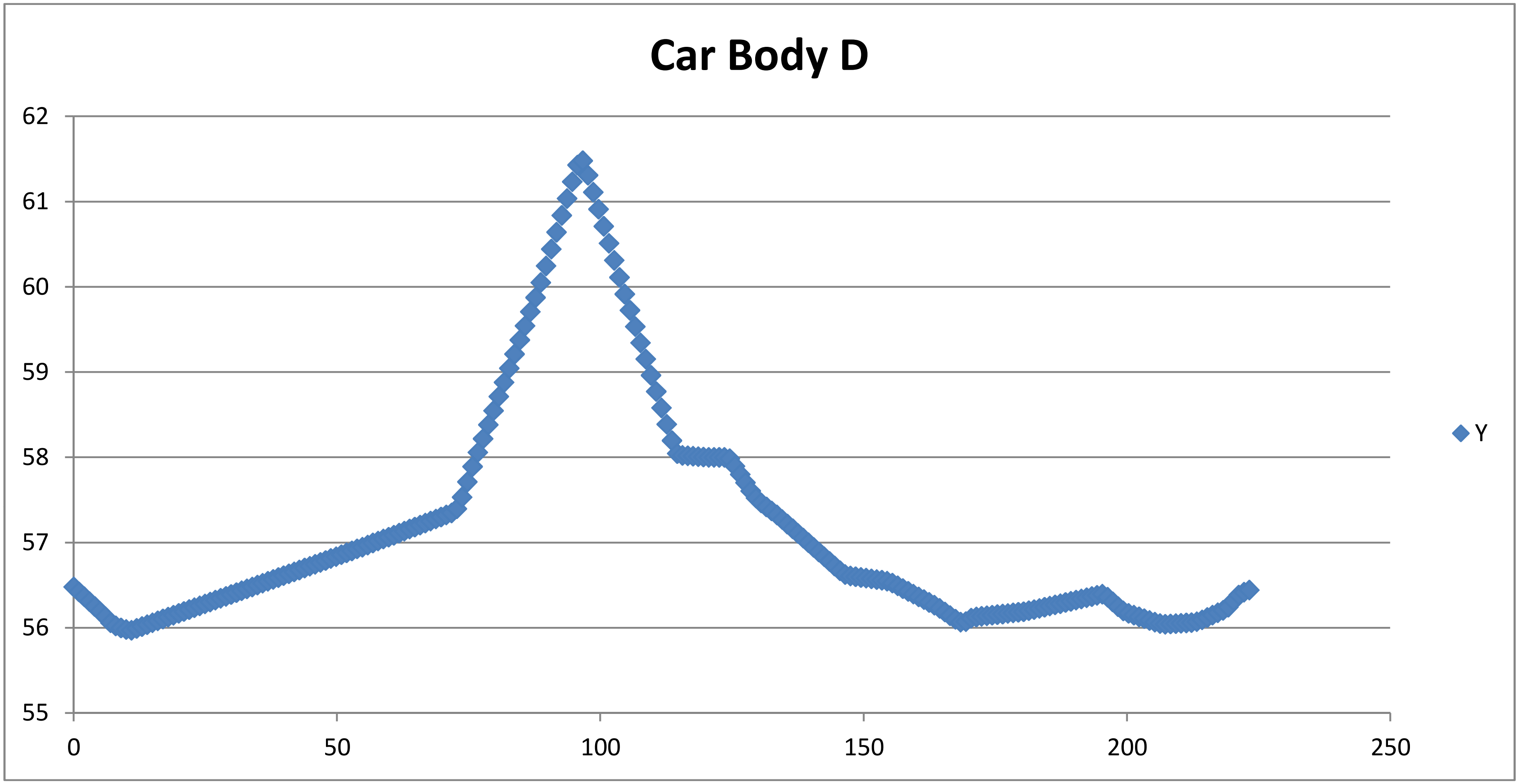

Skokomish GI: Car Body Levee Profiles with Cross Sections [05FEB2013]
N
A
B
C
D
E
F
G
Cross Sections
Split Lines
Landward Toe Profile
Levee Profile
Riverward Toe Profile
0 150 300 600 900 1,200 1,500 1,800 2,100 2,400 2,700 3,000 3,300 3,600
Feet

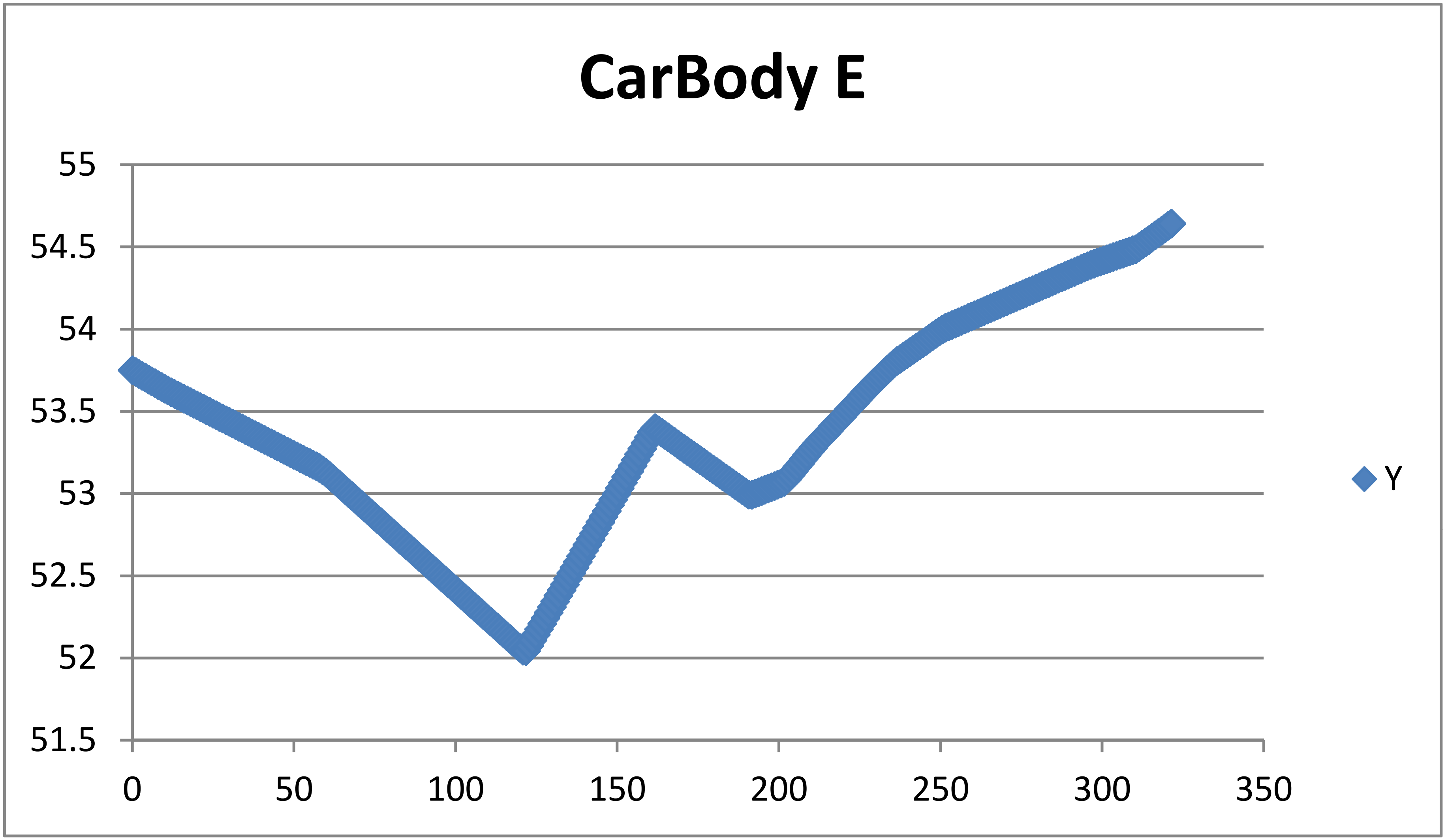

Car Body Levee Profiles with Cross Section Locations (NAVD88 FT)
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
A
B
C
D
E
F
G
930 FT
281 FT
577 FT
616 FT
65
957 FT
1167 FT
0 200 400 600 800 1,000 1,200 1,400 1,600 1,800 2,000 2,200 2,400 2,600 2,800 3,000 3,200 3,400 3,600 3,800 4,000 4,200 4,400 4,600

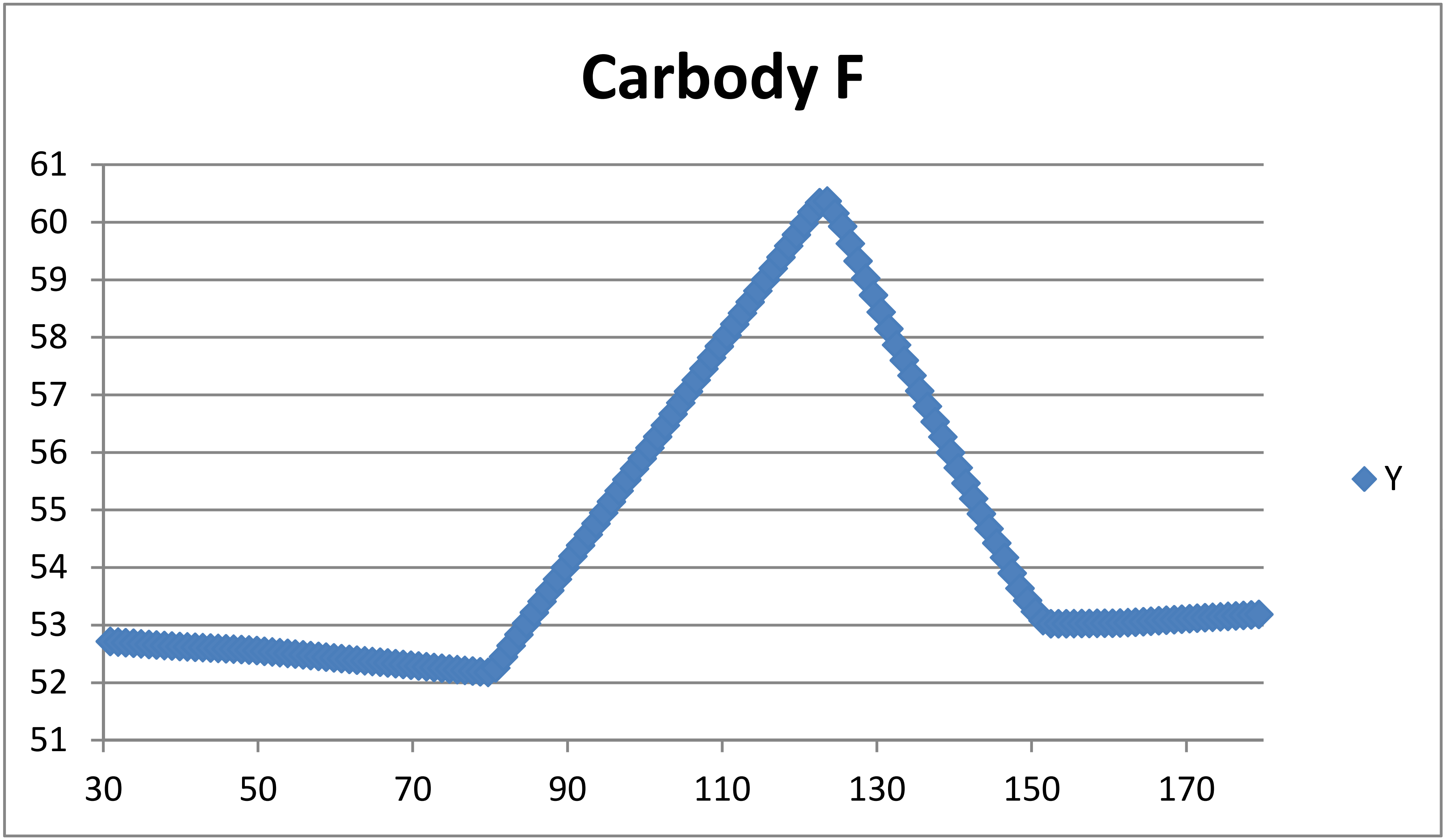

Car Body A
68
67
66
65
64
63
62
61
60
59
58
57
100
120
140
160
180
200
220
Y



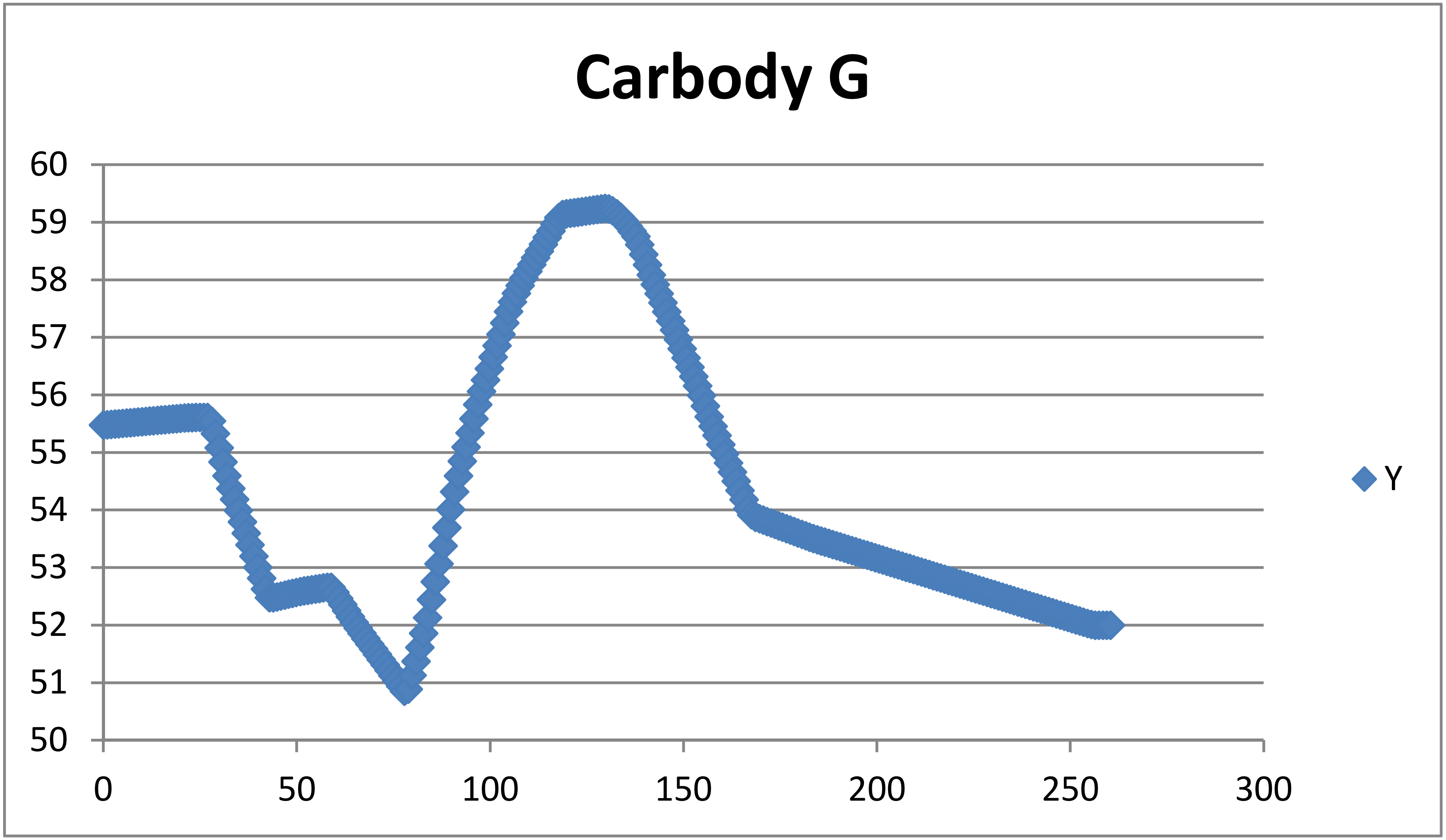
Car Body Levee Section C
68
67
66
65
64
63
62
61
60
59
58
57
50
70
90
110
130
150
170
Y


Car Body D
62
61
60
59
58
57
56
55
0
50
100
150
200
250
Y


CarBody E
55
54.5
54
53.5
53
52.5
52
51.5
0
50
100
150
200
250
300
350
Y

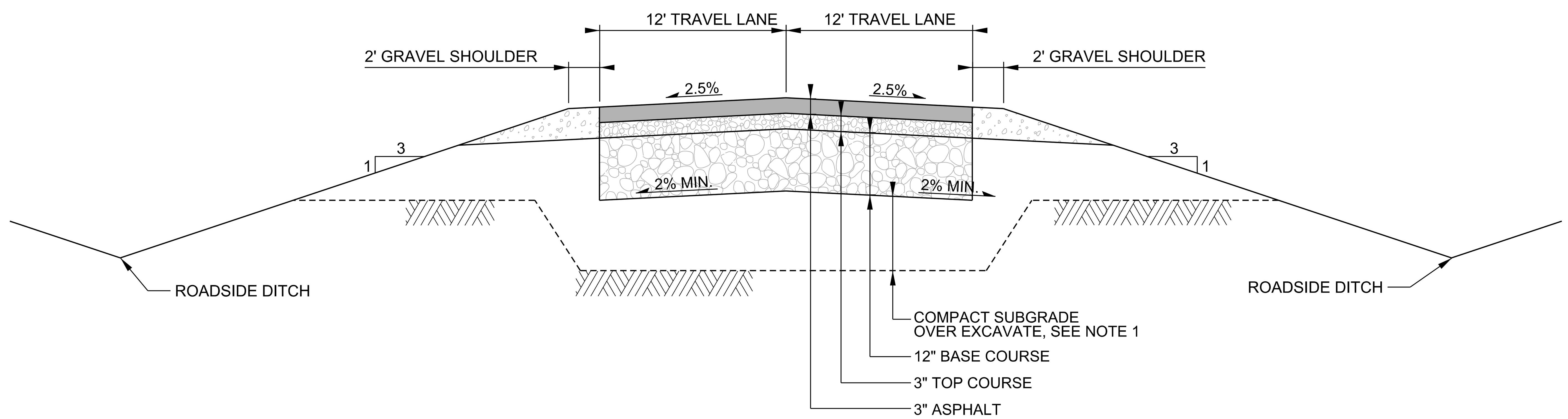


Carbody F
61
60
59
58
57
56
55
54
53
52
51
30
50
70
90
110
130
150
170
Y


Carbody G
60
59
58
57
56
55
54
53
52
51
50
0
50
100
150
200
250
300
Y

Dips Road Calculations

Road Realignment



SKOKOMISH VALLEY ROAD RE-ALIGNMENT TYPICAL SECTION

NOT TO SCALE

NOTES:

1. REMOVE ORGANIC SOILS FROM FOUNDATION. OVER EXCAVATE 24" - 36" AND REPLACE WITH SUITABLE MATERIAL.
2. SIZE RIVERSIDE DITCH AT 2% SLOPE FOR CONVEYANCE. SIZE BIOSWALE ON LANDSIDE OF PROPOSED ROADWAY FOR WATER QUALITY IN COMPLIANCE WITH WASHINGTON DEPARTMENT OF ECOLOGY: STORMWATER MANAGEMENT MANUAL FOR WESTERN WASHINGTON.
3. ASSUME 1 DETENTION POND/250 LF FOR FLOW CONTROL IN COMPLIANCE WITH WASHINGTON DEPARTMENT OF ECOLOGY: STORMWATER MANAGEMENT MANUAL FOR WESTERN WASHINGTON.
4. RECOMMEND ROAD BE ELEVATED APPROXIMATELY 1.0' FOR DRAINAGE.
5. *12-FOOT TRAVEL LANE IS ASSUMED FOR CONCEPTUAL DESIGN TO ACCOUNT FOR CURVATURE IN DESIGN. LOCAL SPONSOR REQUESTED 11-FOOT TRAVEL LANES PER NOVEMBER 9, 2012 EMAIL.
5. PRELIMINARY ALIGNMENT LENGTH APPROX. 3,900 LF

APPROX. ROAD SECTION VOLUME CY					
PAVEMENT	TOP COURSE	BASE COURSE	GRAVEL SHOULDERS	OVER EXCAVATION	FILL
870	870	3,470	400	10,120	11,560

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SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: MAY
DWN BY: RR
CKD BY:
SUBMITTED BY:
PLOT DATE: 2/14/2013
PLOT TIME: 4:47:30 PM
SIZE: ANSI D
FILE NAME: PN60344_SKOK-C-ROAD-RE-ALIGNMENT.DGN
DATE: DD MONTH 2011
SOLICITATION NO.: X000XX-00-X-0002
CONTRACT NO.: X000XX-00X-0000
FILE NUMBER: E-25-1-22

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832

ALTERNATIVE 1

SHEET IDENTIFICATION
C-301
SHEET OF

DESIGN FILE: c:\users\g3ecdrd9\documents\cenws01\dms73333\PN60344_SKOK-C-ROAD-RE-ALIGNMENT.DGN

DATE AND TIME PLOTTED: $$$DATE$$$$

U.S. ARMY CORPS OF ENGINEERS

PROJECT: Skok River Ecosystem Rest. GI	COMPUTED BY: Rosa Radding	DATE: 13-Feb-2013
SUBJECT: New Dips Road Section Materials	CHECKED BY:	SHT. 1 of 1

New Road Section

Pavement Depth =	0.25	ft
Top Course Depth=	0.25	ft
Base Course=	1	ft
Gravel Shoulders Width=	2	ft
Side Slopes=	3	H:1V
Proposed Alignment Length=	3900	ft
Travel Lanes Width=	12	ft

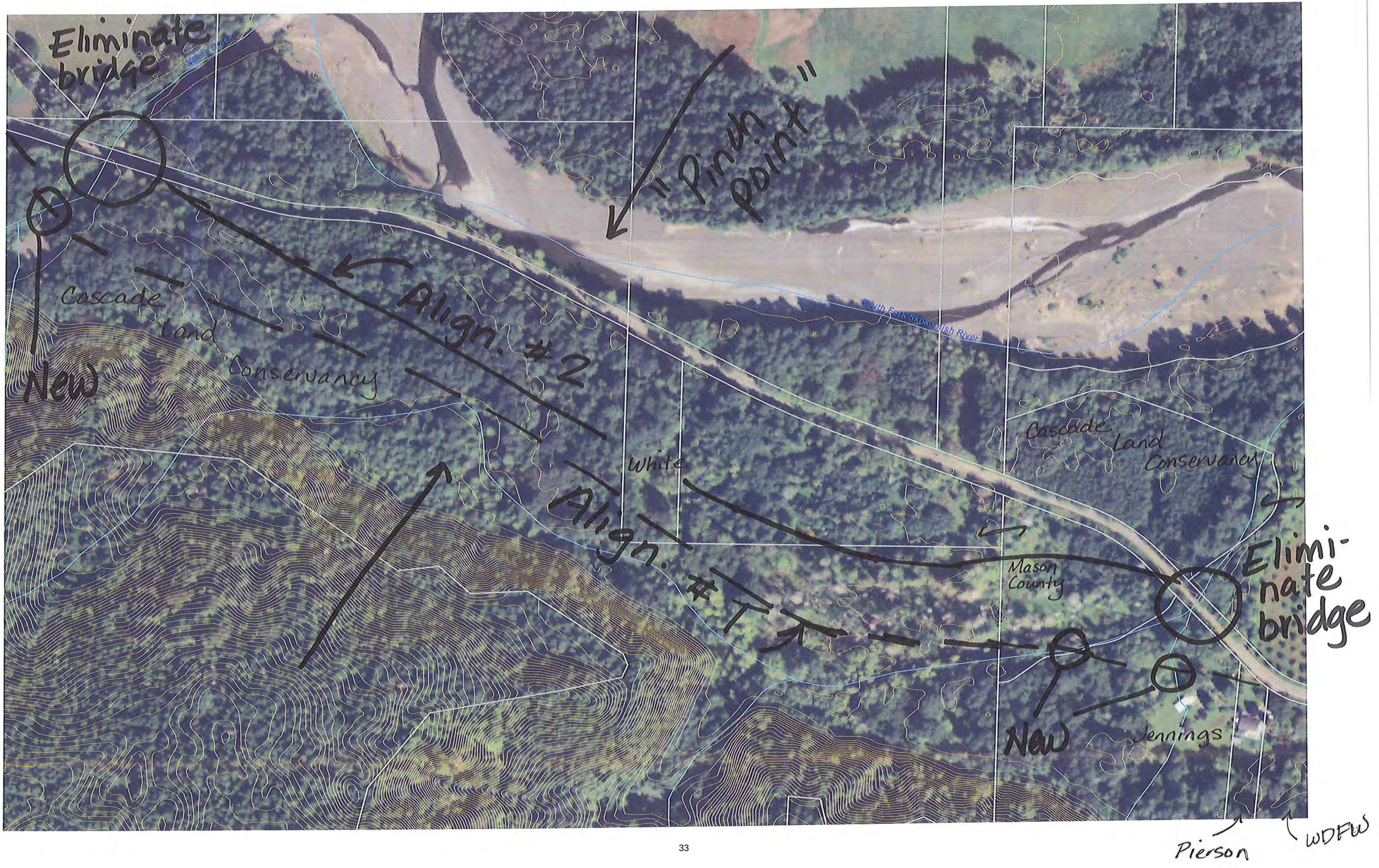
Assumptions:

1.) 12' travel lanes ares assumed for Concept Design to account for Curvature. Local Sponsor requested 11-Foot Travel Lanes per Nov 9, 2012

2.) 2.5 Ft overexcavation of organic soils

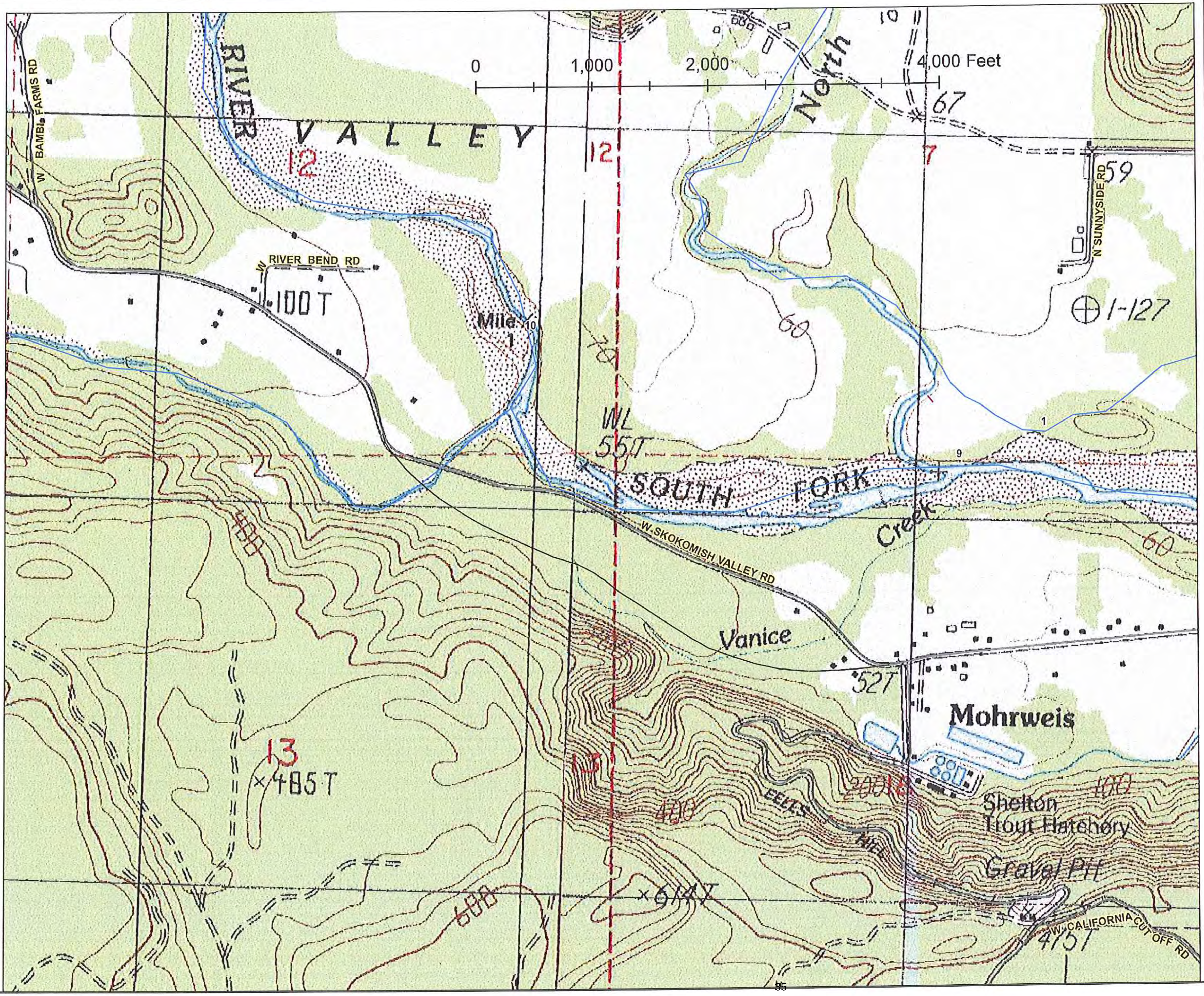
Volume Calcs for New Road Section

Pavement =	867	CY
Top Course=	867	CY
Base Course=	3,467	CY
Gravel shoulders=	397	CY
Over Excavation=	10,111	CY
Fill=	11,556	CY



Eliminate bridge
"Pinch point"
South Fork Skokomish River
Cascade Land Conservancy
New
Align. #2
White
Align. #1
Cascade Land Conservancy
Mason County
Eliminate bridge
New
Jennings
Pierson
WDFW


North Fork Skokomish River
South Fork Skokomish River
Skokomish River
Weaver Creek



N

Sheet 1 of 1

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DRAFT

Notes:

Created by: RR	Date: 01-NOV-2012
Section: Civil Engineering	File Name: SkokomishGI_ALT#1_01NOV2012
Coordinate System: NAD_1983_StatePlane_WA_North	Datum: D_North_American_1983
Path: V:\Civil\Skokomish River GIS, Project Photos, Maps & Drawings\Maps	

Add on #1:
Roadway

SKOKOMISH RIVER GI

Mason County

WASHINGTON STATE

Enclosure
1

From: Rich Geiger [rjgeiger@masoncd.org]
Sent: Tuesday, November 13, 2012 2:23 PM
To: Radding, Rosa NWS
Subject: FW: Fwd: FW: Skokomish River Basin: Roadway Relocation Data (UNCLASSIFIED)
Attachments: dips prelim alignment_11.2012.pdf

Hello, Rosa. Mason County provided the attached road alignments and other answers to your questions (below). Please let me know if you have any questions. - Rich

From: Loretta Swanson [mailto:LorettaS@co.mason.wa.us]
Sent: Friday, November 09, 2012 10:20 AM
To: Rich Geiger
Cc: Brian Matthews; Charles Greninger; Melissa McFadden
Subject: Re: Fwd: FW: Skokomish River Basin: Roadway Relocation Data (UNCLASSIFIED)

Rich,

Per Melissa's request, the ADT and cross section information is below in red. (Chuck Greninger provided the ADT and cross section information from mobility.)
We offer the following observations regarding the alignment:

1. The proposed alignment (see Alignment #1 on attached PDF) will require at least two new bridges (perhaps 3-4). Is it important from a hydraulic standpoint to improve the existing crossings, or can the new alignment occur between the existing bridges (see Alignment #2)?
2. We have a potential "pinch point" between the South Fork and Swift Creek.
3. May be a challenge to align @ 90 degrees.
4. The proposed alignment would involve WDFW, two private property owners with residences, and the Cascade Land Conservancy.

Let us know if you need anything further, Rich. Thanks!

Loretta Swanson

Stormwater Program Coordinator/Program Manager

100 W Public Works Drive

Shelton, WA 98584

(360) 427-9670 Ext. 769

>>> Melissa McFadden 11/9/2012 8:31 AM >>>

Skokomish Valley Road is an 08 (Rural Minor Collector) - According to Title 16, proposed roadway width will need to be 28' with a minimum of 20' of that paved. I would like to see 2-11' lanes (paved) + 2-3' shoulders (gravel).

In addition to the cross section required at this location, Rich called to ask for ADT data (vicinity of the "dips") (The most recent count in mobility was collected 7/2009 and ADT = 992), and I thought he had wanted existing cross section data (The existing cross section in that vicinity is two 12-foot wide ACP lanes with 2-foot gravel shoulders.). I will ask Chuck to provide the last 2 items to you, Loretta. Will you provide feedback to Rich today or next week sometime?

Thank you!!!

MM

>>> Rich Geiger <rjgeiger@masoncd.org> 11/8/2012 2:37 PM >>>
Hello, Melissa. Please have a look at the attached road realignment proposed by USACE for the Skokomish Valley road realignment. Also, please let us know what the road cross section we should use at this location. Specifically, we need to know the required lane and shoulder widths - I recall (but need to check with you) the typical county road section having a 1.0' base course, 0.25' crushed surfacing top course and 0.25' pavement, and you mentioned a 2.5% cross slope from the road crown.
Thanks very much! - Rich

-----Original Message-----
From: Radding, Rosa NWS [mailto:Rose.Radding@usace.army.mil]
Sent: Thursday, November 08, 2012 1:13 PM
To: Rich Geiger
Cc: Brouwer, Mamie S NWS; May, Kim S NWS
Subject: RE: Skokomish River Basin: Roadway Relocation Data (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: NONE

Rich,
The PDT has reconvened to produce 10% designs. For that effort I was wondering what the county has in mind for the roadway relocation. Is the attached somewhat like what you have in mind?
Better yet, can you put a line on the map showing what alignment the county is looking for? And could you send also the county's roadway section?

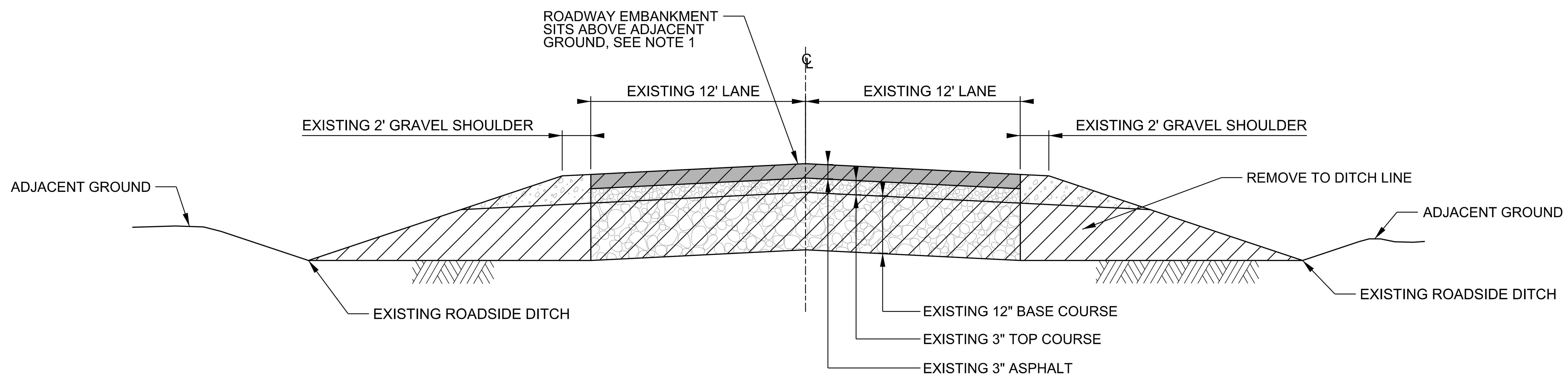
Thanks so much,

Rosa Radding
Civil Engineer
Civil Section, Engineering Branch
USACE- Seattle District
4735 East Marginal Way South
Seattle, WA 98134-2385
P: (206) 764-6965
F: (206) 764-6795
E: rose.radding@usace.army.mil

Classification: UNCLASSIFIED
Caveats: NONE

Dips Road Calculations

Existing Road Degrade



1 C-301 TYPICAL EXISTING SKOKOMISH VALLEY ROAD TO BE REMOVED
NOT TO SCALE

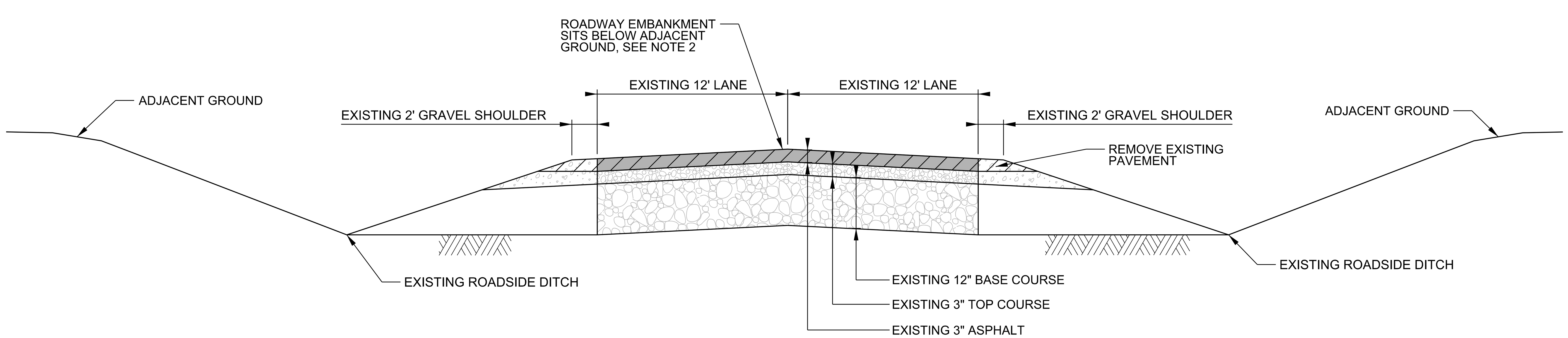
NOTES:

1. REMOVE ROADBED TO DITCH LINE WHERE ROADWAY EMBANKMENT SITS ABOVE ADJACENT GROUND. SEE SECTION 1.

2. REMOVE EXISTING PAVEMENT WEARING COURSE WHERE ROADWAY SITS LOWER THAN ADJACENT GROUND. SEE SECTION 2.

ESTIMATED VOLUME EXCAVATION MATERIAL		
PAVEMENT (CY)	BASE COURSE AND CRUSHED GRAVEL (CY)	EMBANKMENT FILL (CY)
900	1800	400

LEGEND	
▨	REMOVE MATERIAL



2 C-301 TYPICAL EXISTING SKOKOMISH VALLEY ROAD TO BE REMOVED
NOT TO SCALE

US Army Corps of Engineers®
SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: MAY
DWN BY: RR
CKD BY:
SUBMITTED BY:
PLOT DATE: 1/28/2013
PLOT TIME: 2:27:25 PM
SIZE: ANSI D
FILE NAME: PN60344_SKOK-C-SED_TRP-RD_DEMO.DGN
DATE: DD MONTH 2011
SOLICITATION NO.: X000XX-00-X-0002
CONTRACT NO.: X000XX-00X-0000
FILE NUMBER: E-25-1-22

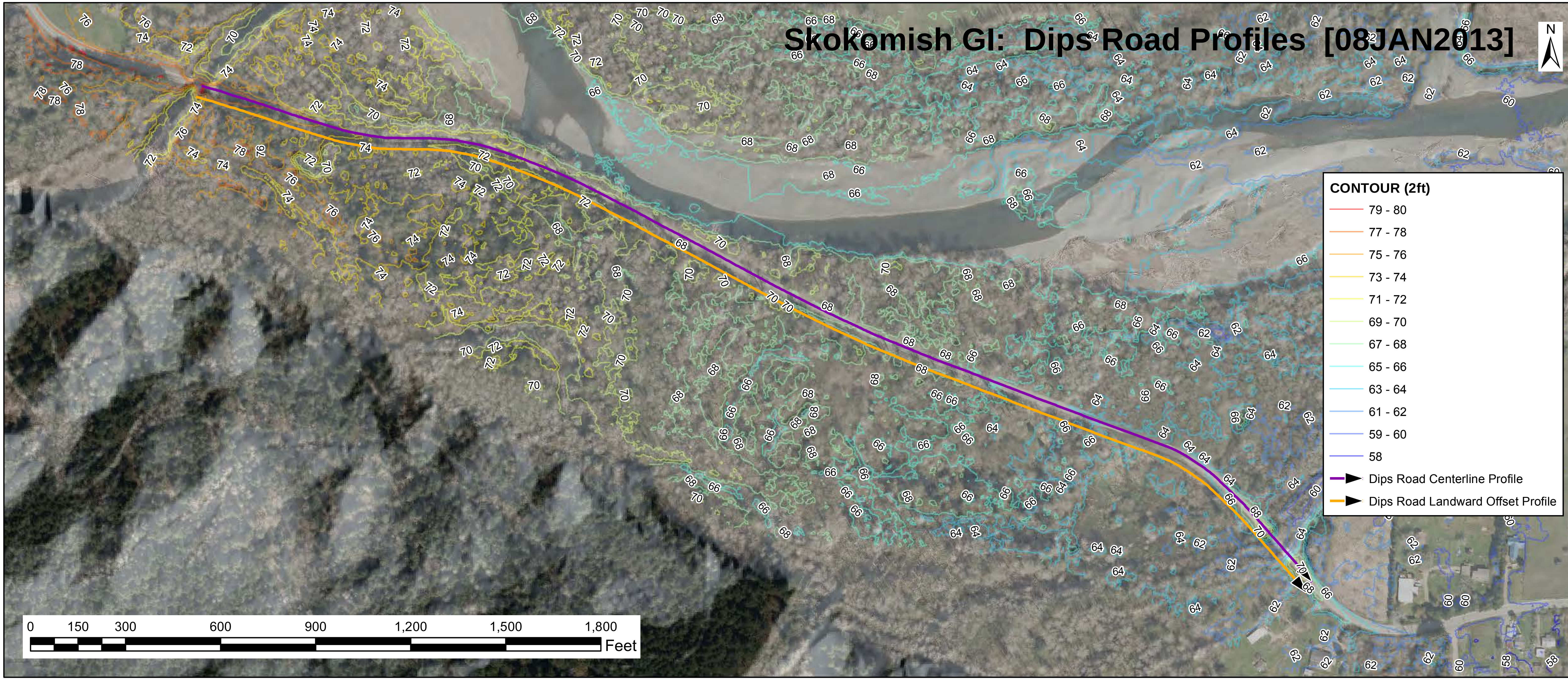
SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832

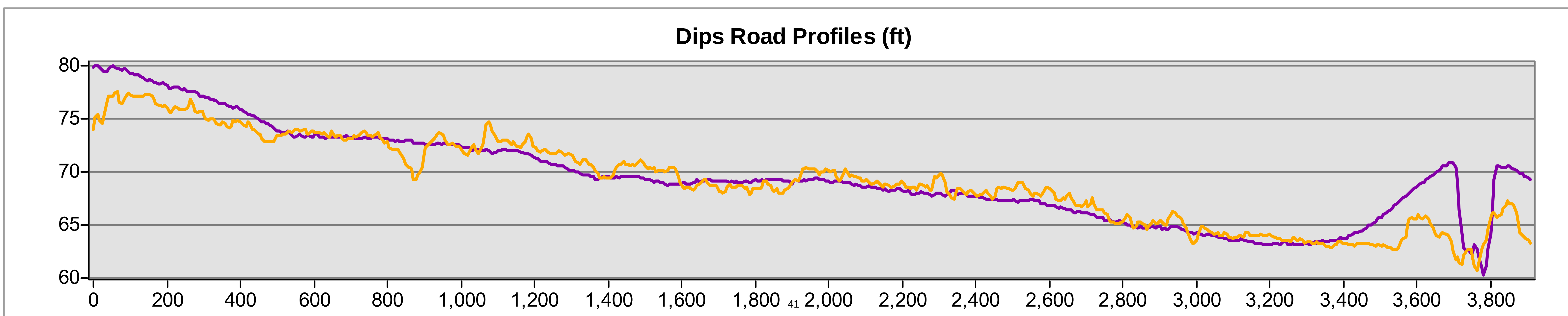
ROAD DEMOLITION

SHEET IDENTIFICATION
C-301
SHEET OF

DESIGN FILE: c:\users\g3ecdlal\documents\cenws01\dms73333\PN60344_SKOK-C-SED_TRP-RD_DEMO.DGN

DATE AND TIME PLOTTED: $$$DATE$$$$


Skokomish GI: Dips Road Profiles [08JAN2013]
N
CONTOUR (2ft)
79 - 80
77 - 78
75 - 76
73 - 74
71 - 72
69 - 70
67 - 68
65 - 66
63 - 64
61 - 62
59 - 60
58
Dips Road Centerline Profile
Dips Road Landward Offset Profile
0 150 300 600 900 1,200 1,500 1,800
Feet


Dips Road Profiles (ft)
80
75
70
65
60
0 200 400 600 800 1,000 1,200 1,400 1,600 1,800 2,000 2,200 2,400 2,600 2,800 3,000 3,200 3,400 3,600 3,800

landward off set X	Y	Dips Profile X	Y	Grade Diff	Grade difference between roadbed and adjacent ground	Grade difference where roadbed is higher than adjacent grade	Distance in feet along profile where roadway is higher than adjacent ground	Average depth of excavation along this distance
0	73.99475	0	79.81622	5.8	1.50	1.50		
5.841919	75.17502	5.841919	79.95033	4.8	1.50	1.50		
11.68384	75.43656	11.68384	79.99616	4.6	1.50	1.50		
17.52576	74.8538	17.52576	79.82418	5.0	1.50	1.50		
23.36768	74.5491	23.36768	79.6185	5.1	1.50	1.50		
29.2096	75.21407	29.2096	79.46209	4.2	1.50	1.50		
35.05152	76.53956	35.05152	79.44115	2.9	1.50	1.50		
40.89343	77.15123	40.89343	79.74691	2.6	1.50	1.50		
46.73535	77.13774	46.73535	79.79103	2.7	1.50	1.50		
52.57727	77.16072	52.57727	79.95171	2.8	1.50	1.50		
58.41919	77.35072	58.41919	79.85341	2.5	1.50	1.50		
64.38413	77.54899	64.38413	79.74376	2.2	1.50	1.50		
70.34907	76.49379	70.34907	79.7415	3.2	1.50	1.50		
76.314	76.36492	76.314	79.55537	3.2	1.50	1.50		
82.27894	76.66708	82.27894	79.67339	3.0	1.50	1.50		
88.24388	77.05134	88.24388	79.66007	2.6	1.50	1.50		
94.20881	77.38453	94.20881	79.41141	2.0	1.50	1.50		
100.1738	77.32577	100.1738	79.28418	2.0	1.50	1.50		
106.1387	77.11053	106.1387	79.22372	2.1	1.50	1.50		
111.9933	77.08866	111.9933	79.07991	2.0	1.50	1.50		
117.8478	77.16878	117.8478	79.07827	1.9	1.50	1.50		
123.7024	77.13599	123.7024	79.14551	2.0	1.50	1.50		
129.6049	77.12592	129.6049	78.98484	1.9	1.50	1.50		
135.5074	77.16938	135.5074	78.85335	1.7	1.50	1.50		
141.4099	77.22644	141.4099	78.70811	1.5	1.48	1.48		
147.3123	77.25204	147.3123	78.55227	1.3	1.30	1.30		
153.2148	77.22718	153.2148	78.68219	1.5	1.46	1.46		
159.1173	77.14976	159.1173	78.60966	1.5	1.46	1.46		
165.0198	76.85382	165.0198	78.47658	1.6	1.50	1.50		
170.9222	76.43999	170.9222	78.48774	2.0	1.50	1.50		
176.8247	76.28601	176.8247	78.33123	2.0	1.50	1.50		
182.7272	76.28225	182.7272	78.33142	2.0	1.50	1.50		
188.6297	76.1973	188.6297	78.3747	2.2	1.50	1.50		
194.5321	76.20328	194.5321	78.30911	2.1	1.50	1.50		
200.4346	76.05055	200.4346	78.15525	2.1	1.50	1.50		
206.3371	75.64872	206.3371	77.8984	2.2	1.50	1.50		
212.242	75.58966	212.242	77.79156	2.2	1.50	1.50		
218.1469	75.99888	218.1469	77.92886	1.9	1.50	1.50		
224.0519	76.17508	224.0519	78.02491	1.8	1.50	1.50		
229.9568	76.01571	229.9568	78.0348	2.0	1.50	1.50		
235.8617	75.88267	235.8617	77.87161	2.0	1.50	1.50		
241.7666	75.79204	241.7666	77.75421	2.0	1.50	1.50		
247.6715	75.80438	247.6715	77.83449	2.0	1.50	1.50		
253.5765	75.98532	253.5765	77.62147	1.6	1.50	1.50		
259.4814	76.21775	259.4814	77.56994	1.4	1.35	1.35		
265.3863	76.80702	265.3863	77.57718	0.8	0.77	0.77		
271.2912	76.21082	271.2912	77.55705	1.3	1.35	1.35		
277.1961	75.72211	277.1961	77.53599	1.8	1.50	1.50		
283.1011	75.54909	283.1011	77.39346	1.8	1.50	1.50		
289.006	75.74675	289.006	77.18566	1.4	1.44	1.44		
294.9109	75.6771	294.9109	77.14536	1.5	1.47	1.47		
300.8158	75.32185	300.8158	77.07263	1.8	1.50	1.50		
306.7208	74.95753	306.7208	77.04357	2.1	1.50	1.50		
312.6257	74.79736	312.6257	76.99866	2.2	1.50	1.50		
318.311	74.92235	318.311	76.84626	1.9	1.50	1.50		
323.9963	74.97868	323.9963	76.78242	1.8	1.50	1.50		
329.6816	74.87093	329.6816	76.63113	1.8	1.50	1.50		
335.3669	74.5926	335.3669	76.63734	2.0	1.50	1.50		
341.0522	74.40577	341.0522	76.38238	2.0	1.50	1.50		
346.7375	74.48119	346.7375	76.44857	2.0	1.50	1.50		
352.4228	74.69674	352.4228	76.47757	1.8	1.50	1.50		
358.1081	74.54164	358.1081	76.37322	1.8	1.50	1.50		
363.7934	74.31702	363.7934	76.27332	2.0	1.50	1.50		
369.4787	74.11252	369.4787	76.19145	2.1	1.50	1.50		
375.164	74.33487	375.164	76.06972	1.7	1.50	1.50		
380.8493	74.77859	380.8493	76.0266	1.2	1.25	1.25		
386.5346	74.73544	386.5346	76.06569	1.3	1.33	1.33		
392.2199	74.79986	392.2199	76.0858	1.3	1.29	1.29		
397.9052	74.65743	397.9052	75.87262	1.2	1.22	1.22		
403.5905	74.50818	403.5905	75.85038	1.3	1.34	1.34		
409.2758	74.33974	409.2758	75.70192	1.4	1.36	1.36		
414.7899	74.3178	414.7899	75.56163	1.2	1.24	1.24		
420.3041	74.69249	420.3041	75.4522	0.8	0.76	0.76		
425.8183	74.52192	425.8183	75.38215	0.9	0.86	0.86		
431.3324	74.04992	431.3324	75.28918	1.2	1.24	1.24		
436.8466	73.93211	436.8466	75.2072	1.3	1.28	1.28		
442.3608	73.80209	442.3608	75.16526	1.4	1.36	1.36		
447.875	73.54842	447.875	75.00746	1.5	1.46	1.46		

Notes	
Estimated Pavement Removal CY	**869**
Estimated Area of Base Course Length x Ave Depth SF	1,695
Estimated Volume of Base Course Length x Ave Depth x Width CY	**1,758**
*Estimated Volume of Earthwork for grading CY	**388**
*Assuming road embankment side slopes 3H:1V 1.5 Ft depth.	

453.3891	73.58423	453.3891	74.80362	1.2	1.22	1.22			
458.9033	73.13765	458.9033	74.72357	1.6	1.50	1.50			
464.4175	72.8549	464.4175	74.64781	1.8	1.50	1.50			
469.6152	72.80685	469.6152	74.58369	1.8	1.50	1.50			
474.8128	72.8053	474.8128	74.48182	1.7	1.50	1.50			
480.0105	72.81169	480.0105	74.33821	1.5	1.50	1.50			
485.2082	72.8154	485.2082	74.23685	1.4	1.42	1.42			
490.4059	72.90188	490.4059	74.14677	1.2	1.24	1.24			
495.6036	73.13406	495.6036	74.03649	0.9	0.90	0.90			
500.8013	73.3374	500.8013	73.90728	0.6	0.57	0.57			
506.2362	73.43627	506.2362	73.77899	0.3	0.34	0.34			
511.6711	73.43773	511.6711	73.69702	0.3	0.26	0.26			
517.106	73.48069	517.106	73.67444	0.2	0.19	0.19			
522.5409	73.62082	522.5409	73.64164	0.0	0.02	0.02			
527.9758	73.68303	527.9758	73.76712	0.1	0.08	0.08	533.4	1.35	for ~530 feet the roadbed is higher than the adjacent grade and we will excavate approx 1.4 feet.
533.4106	73.8227	533.4106	73.69046	-0.1	-0.13	0.00			
538.8455	73.67253	538.8455	73.47845	-0.2	-0.19	0.00			
544.2804	73.77725	544.2804	73.31354	-0.5	-0.46	0.00			
549.7153	73.97934	549.7153	73.33395	-0.6	-0.65	0.00			
555.1502	74.00151	555.1502	73.45991	-0.5	-0.54	0.00			
560.5299	73.8974	560.5299	73.50718	-0.4	-0.39	0.00			
565.9096	73.89683	565.9096	73.41328	-0.5	-0.48	0.00			
571.2893	73.94159	571.2893	73.30922	-0.6	-0.63	0.00			
576.669	73.99731	576.669	73.29359	-0.7	-0.70	0.00			
582.0487	73.51605	582.0487	73.38906	-0.1	-0.13	0.00			
587.4284	73.54652	587.4284	73.3569	-0.2	-0.19	0.00			
592.8081	73.83073	592.8081	73.24178	-0.6	-0.59	0.00			
598.1878	73.77284	598.1878	73.29398	-0.5	-0.48	0.00			
603.5675	73.64765	603.5675	73.5154	-0.1	-0.13	0.00			
609.2105	73.68354	609.2105	73.50399	-0.2	-0.18	0.00			
614.8535	73.72488	614.8535	73.26075	-0.5	-0.46	0.00			
620.4965	73.60885	620.4965	73.25742	-0.4	-0.35	0.00			
626.1396	73.64132	626.1396	73.22347	-0.4	-0.42	0.00			
631.7826	73.49308	631.7826	73.16648	-0.3	-0.33	0.00			
637.4256	73.25142	637.4256	73.28963	0.0	0.04	0.04			
643.0687	73.20424	643.0687	73.30357	0.1	0.10	0.10			
648.7117	73.76932	648.7117	73.20604	-0.6	-0.56	0.00			
654.269	73.38761	654.269	73.21011	-0.2	-0.18	0.00			
659.8263	73.32349	659.8263	73.27894	0.0	-0.04	0.00			
665.3836	73.38655	665.3836	73.20417	-0.2	-0.18	0.00			
670.9409	73.39974	670.9409	73.21573	-0.2	-0.18	0.00			
676.4981	73.17509	676.4981	73.25439	0.1	0.08	0.08			
681.8553	72.99967	681.8553	73.30396	0.3	0.30	0.30			
687.2124	73.00351	687.2124	73.39042	0.4	0.39	0.39			
692.5696	73.05241	692.5696	73.3036	0.3	0.25	0.25			
697.9267	73.06051	697.9267	73.12996	0.1	0.07	0.07			
703.2839	73.17599	703.2839	73.19898	0.0	0.02	0.02			
708.641	73.36411	708.641	73.07927	-0.3	-0.28	0.00			
713.9981	73.3268	713.9981	73.12797	-0.2	-0.20	0.00			
719.5537	73.46142	719.5537	73.07248	-0.4	-0.39	0.00			
725.1093	73.546	725.1093	73.10748	-0.4	-0.44	0.00			
730.6648	73.65439	730.6648	73.19059	-0.5	-0.46	0.00			
736.2204	73.84403	736.2204	73.22121	-0.6	-0.62	0.00			
741.7759	73.70363	741.7759	73.21285	-0.5	-0.49	0.00			
747.3315	73.45376	747.3315	73.18514	-0.3	-0.27	0.00			
752.9012	73.36664	752.9012	73.17995	-0.2	-0.19	0.00			
758.4709	73.27653	758.4709	73.25271	0.0	-0.02	0.00			
764.0406	73.39166	764.0406	73.23014	-0.2	-0.16	0.00			
769.6103	73.54763	769.6103	73.19761	-0.4	-0.35	0.00			
775.18	73.64291	775.18	73.29808	-0.3	-0.34	0.00			
780.7497	73.31272	780.7497	73.18199	-0.1	-0.13	0.00	252.8	0.25	~255 feet along which the roadway is lower than adjacent ground and only 3" of pavement is removed.
786.3194	72.9121	786.3194	73.13865	0.2	0.23	0.23			
792.2925	72.67739	792.2925	73.1388	0.5	0.46	0.46			
798.2655	72.82595	798.2655	73.16089	0.3	0.33	0.33			
804.2385	72.32179	804.2385	72.97163	0.6	0.65	0.65			
810.2115	72.11038	810.2115	73.02171	0.9	0.91	0.91			
816.1845	72.14548	816.1845	73.00373	0.9	0.86	0.86			
822.1575	72.09587	822.1575	72.90383	0.8	0.81	0.81			
828.1305	72.0892	828.1305	72.91308	0.8	0.82	0.82			
833.5977	71.81029	833.5977	72.87551	1.1	1.07	1.07			
839.0649	71.44188	839.0649	72.86465	1.4	1.42	1.42			
844.532	71.14888	844.532	72.89516	1.7	1.50	1.50			
849.9992	70.73562	849.9992	72.96181	2.2	1.50	1.50			
855.4663	70.40934	855.4663	73.02548	2.6	1.50	1.50			
860.9335	70.39787	860.9335	72.92442	2.5	1.50	1.50			
866.4007	70.21311	866.4007	72.91054	2.7	1.50	1.50			
871.8489	69.23341	871.8489	72.76195	3.5	1.50	1.50			
877.2971	69.28965	877.2971	72.6249	3.3	1.50	1.50			
882.7453	69.6772	882.7453	72.6556	3.0	1.50	1.50			
888.1936	69.77888	888.1936	72.7225	2.9	1.50	1.50			
893.6418	70.42177	893.6418	72.70976	2.3	1.50	1.50			
899.09	71.45803	899.09	72.6492	1.2	1.19	1.19			
904.5383	72.25098	904.5383	72.59023	0.3	0.34	0.34			
910.5343	72.61261	910.5343	72.57642	0.0	-0.04	0.00	129.8	1.05	for ~130 feet the roadway sections are higher than existing ground and we will excavate on average 1 foot of roadbed.
916.5303	72.67215	916.5303	72.55081	-0.1	-0.12	0.00			
922.5264	72.93752	922.5264	72.60027	-0.3	-0.34	0.00			

928.5224	73.05781	928.5224	72.60728	-0.5	-0.45	0.00
934.5184	73.61783	934.5184	72.62515	-1.0	-0.99	0.00
940.5145	73.722	940.5145	72.62209	-1.1	-1.10	0.00
946.5105	73.57744	946.5105	72.51652	-1.1	-1.06	0.00
952.3426	73.38849	952.3426	72.7326	-0.7	-0.66	0.00
958.1748	72.92426	958.1748	72.67552	-0.2	-0.25	0.00
964.0069	72.4895	964.0069	72.60096	0.1	0.11	0.11
969.839	72.60255	969.839	72.54186	-0.1	-0.06	0.00
975.6712	72.67435	975.6712	72.58047	-0.1	-0.09	0.00
981.5033	72.51842	981.5033	72.56464	0.0	0.05	0.05
987.3354	72.42735	987.3354	72.5608	0.1	0.13	0.13
993.1675	72.35126	993.1675	72.53165	0.2	0.18	0.18
998.9997	72.21858	998.9997	72.40819	0.2	0.19	0.19
1004.933	71.83314	1004.933	72.276	0.4	0.44	0.44
1010.866	71.62381	1010.866	72.21931	0.6	0.60	0.60
1016.8	71.53319	1016.8	72.27143	0.7	0.74	0.74
1022.733	71.76225	1022.733	72.23408	0.5	0.47	0.47
1028.666	72.39867	1028.666	72.02385	-0.4	-0.37	0.00
1034.6	72.5517	1034.6	72.12339	-0.4	-0.43	0.00
1040.533	72.09368	1040.533	72.06714	0.0	-0.03	0.00
1046.466	71.73625	1046.466	72.0741	0.3	0.34	0.34
1052.4	71.9038	1052.4	71.98103	0.1	0.08	0.08
1058.333	72.52273	1058.333	71.9597	-0.6	-0.56	0.00
1064.266	73.45211	1064.266	72.03117	-1.4	-1.42	0.00
1069.763	74.37759	1069.763	72.05366	-2.3	-2.32	0.00
1075.26	74.66809	1075.26	71.94879	-2.7	-2.72	0.00
1080.757	74.40375	1080.757	71.80332	-2.6	-2.60	0.00
1086.254	73.89806	1086.254	71.73874	-2.2	-2.16	0.00
1091.751	73.3596	1091.751	71.8709	-1.5	-1.49	0.00
1097.248	73.09441	1097.248	71.89244	-1.2	-1.20	0.00
1102.745	72.88442	1102.745	71.90758	-1.0	-0.98	0.00
1108.242	72.80122	1108.242	71.99279	-0.8	-0.81	0.00
1114.131	72.96816	1114.131	72.05867	-0.9	-0.91	0.00
1120.021	72.92657	1120.021	72.05295	-0.9	-0.87	0.00
1125.91	73.04162	1125.91	71.96664	-1.1	-1.07	0.00
1131.799	72.73502	1131.799	71.95144	-0.8	-0.78	0.00
1137.689	72.60314	1137.689	71.94555	-0.7	-0.66	0.00
1143.578	72.80422	1143.578	71.91363	-0.9	-0.89	0.00
1149.468	72.46542	1149.468	71.96875	-0.5	-0.50	0.00
1155.357	72.34698	1155.357	71.92548	-0.4	-0.42	0.00
1161.247	72.24519	1161.247	71.89366	-0.4	-0.35	0.00
1167.136	72.49169	1167.136	71.78253	-0.7	-0.71	0.00
1173.025	72.82837	1173.025	71.71109	-1.1	-1.12	0.00
1178.915	73.26309	1178.915	71.72044	-1.5	-1.54	0.00
1184.881	73.52081	1184.881	71.6237	-1.9	-1.90	0.00
1190.846	73.06069	1190.846	71.47676	-1.6	-1.58	0.00
1196.812	72.40391	1196.812	71.3794	-1.0	-1.02	0.00
1202.778	72.2803	1202.778	71.32777	-1.0	-0.95	0.00
1208.744	71.93402	1208.744	71.21301	-0.7	-0.72	0.00
1214.709	71.84889	1214.709	71.02952	-0.8	-0.82	0.00
1220.675	72.01677	1220.675	71.02851	-1.0	-0.99	0.00
1226.641	72.10294	1226.641	70.99469	-1.1	-1.11	0.00
1232.607	71.92887	1232.607	70.91797	-1.0	-1.01	0.00
1238.573	71.79335	1238.573	70.87966	-0.9	-0.91	0.00
1244.26	71.73548	1244.26	70.71176	-1.0	-1.02	0.00
1249.947	71.62867	1249.947	70.62101	-1.0	-1.01	0.00
1255.634	71.64142	1255.634	70.64677	-1.0	-0.99	0.00
1261.322	71.80251	1261.322	70.60648	-1.2	-1.20	0.00
1267.009	71.91021	1267.009	70.58099	-1.3	-1.33	0.00
1272.696	71.8443	1272.696	70.49259	-1.4	-1.35	0.00
1278.383	71.70672	1278.383	70.4841	-1.2	-1.22	0.00
1284.071	71.55694	1284.071	70.45693	-1.1	-1.10	0.00
1289.758	71.68907	1289.758	70.25407	-1.4	-1.43	0.00
1295.445	71.7157	1295.445	70.08872	-1.6	-1.63	0.00
1301.132	71.58997	1301.132	70.10207	-1.5	-1.49	0.00
1306.82	71.23261	1306.82	70.0569	-1.2	-1.18	0.00
1312.507	71.02888	1312.507	69.94784	-1.1	-1.08	0.00
1318.194	70.87083	1318.194	69.96005	-0.9	-0.91	0.00
1323.881	70.74957	1323.881	69.86924	-0.9	-0.88	0.00
1329.569	71.11026	1329.569	69.65244	-1.5	-1.46	0.00
1335.548	71.16145	1335.548	69.72286	-1.4	-1.44	0.00
1341.528	71.08847	1341.528	69.65168	-1.4	-1.44	0.00
1347.507	70.72237	1347.507	69.63051	-1.1	-1.09	0.00
1353.487	70.64261	1353.487	69.5361	-1.1	-1.11	0.00
1359.466	70.44033	1359.466	69.48522	-1.0	-0.96	0.00
1365.446	70.08026	1365.446	69.22162	-0.9	-0.86	0.00
1371.425	69.88256	1371.425	69.20015	-0.7	-0.68	0.00
1377.405	69.39321	1377.405	69.4299	0.0	0.04	0.04
1383.243	69.42689	1383.243	69.47342	0.0	0.05	0.05
1389.082	69.56104	1389.082	69.43739	-0.1	-0.12	0.00
1394.921	69.43436	1394.921	69.55637	0.1	0.12	0.12
1400.759	69.32535	1400.759	69.52385	0.2	0.20	0.20
1406.598	69.39713	1406.598	69.4137	0.0	0.02	0.02
1412.437	69.63149	1412.437	69.4175	-0.2	-0.21	0.00
1418.276	70.05403	1418.276	69.45209	-0.6	-0.60	0.00
1424.114	70.4493	1424.114	69.47829	-1.0	-0.97	0.00
1429.953	70.7168	1429.953	69.45968	-1.3	-1.26	0.00
1435.792	70.66549	1435.792	69.51093	-1.2	-1.15	0.00
1441.765	70.99007	1441.765	69.48198	-1.5	-1.51	0.00

1447.738	70.75601	1447.738	69.48173	-1.3	-1.27	0.00			
1453.712	70.72535	1453.712	69.52675	-1.2	-1.20	0.00			
1459.685	70.60698	1459.685	69.54632	-1.1	-1.06	0.00			
1465.658	70.73475	1465.658	69.59275	-1.1	-1.14	0.00			
1471.632	70.61053	1471.632	69.55387	-1.1	-1.06	0.00			
1477.605	70.72274	1477.605	69.52566	-1.2	-1.20	0.00			
1483.578	70.90927	1483.578	69.52563	-1.4	-1.38	0.00			
1489.552	71.06776	1489.552	69.44817	-1.6	-1.62	0.00			
1495.525	70.87338	1495.525	69.33141	-1.5	-1.54	0.00			
1501.498	70.51654	1501.498	69.31471	-1.2	-1.20	0.00			
1507.472	70.27957	1507.472	69.22273	-1.1	-1.06	0.00			
1513.445	70.43369	1513.445	69.20066	-1.2	-1.23	0.00			
1519.418	70.31967	1519.418	69.17841	-1.1	-1.14	0.00			
1525.392	70.42948	1525.392	69.0212	-1.4	-1.41	0.00			
1531.365	70.0031	1531.365	69.06614	-0.9	-0.94	0.00			
1537.338	70.16243	1537.338	69.16303	-1.0	-1.00	0.00			
1543.312	70.15777	1543.312	69.00247	-1.2	-1.16	0.00			
1549.189	70.05973	1549.189	68.93175	-1.1	-1.13	0.00			
1555.066	69.99148	1555.066	68.86475	-1.1	-1.13	0.00			
1560.943	70.11486	1560.943	68.66142	-1.5	-1.45	0.00			
1566.82	70.33469	1566.82	68.81565	-1.5	-1.52	0.00			
1572.697	70.33726	1572.697	68.81809	-1.5	-1.52	0.00			
1578.574	70.38122	1578.574	68.82913	-1.6	-1.55	0.00			
1584.451	70.22991	1584.451	68.85031	-1.4	-1.38	0.00			
1590.328	69.48448	1590.328	68.86414	-0.6	-0.62	0.00			
1596.205	68.91545	1596.205	68.87772	0.0	-0.04	0.00	685.7		for ~686 feet the roadbed is lower than ajacent ground and we will only remove the 3 inches of pavement.
1602.082	68.58622	1602.082	68.95505	0.4	0.37	0.37			
1607.959	68.42448	1607.959	68.93083	0.5	0.51	0.51			
1613.836	68.49341	1613.836	68.8316	0.3	0.34	0.34			
1619.713	68.53275	1619.713	68.81141	0.3	0.28	0.28			
1625.478	68.35446	1625.478	68.84566	0.5	0.49	0.49			
1631.242	68.235	1631.242	68.91141	0.7	0.68	0.68			
1637.006	68.41863	1637.006	69.01381	0.6	0.60	0.60			
1642.771	68.656	1642.771	69.28107	0.6	0.63	0.63			
1648.535	68.80223	1648.535	68.99453	0.2	0.19	0.19			
1654.299	69.00748	1654.299	69.10461	0.1	0.10	0.10			
1660.064	69.21018	1660.064	69.13401	-0.1	-0.08	0.00			
1665.828	69.31879	1665.828	69.20878	-0.1	-0.11	0.00			
1671.593	68.99951	1671.593	69.25384	0.3	0.25	0.25			
1677.482	68.73726	1677.482	69.19728	0.5	0.46	0.46			
1683.372	68.61842	1683.372	69.13334	0.5	0.51	0.51			
1689.262	68.7395	1689.262	69.0761	0.3	0.34	0.34			
1695.152	68.73434	1695.152	69.0572	0.3	0.32	0.32			
1701.042	68.10114	1701.042	69.11308	1.0	1.01	1.01			
1706.932	68.11209	1706.932	69.10216	1.0	0.99	0.99			
1712.822	68.01295	1712.822	69.06849	1.1	1.06	1.06			
1718.712	68.10282	1718.712	69.12344	1.0	1.02	1.02			
1724.602	68.47092	1724.602	69.08219	0.6	0.61	0.61			
1730.492	68.83336	1730.492	69.02033	0.2	0.19	0.19			
1736.382	68.57715	1736.382	69.08986	0.5	0.51	0.51			
1742.272	68.51488	1742.272	68.95221	0.4	0.44	0.44			
1748.162	68.59666	1748.162	69.08676	0.5	0.49	0.49			
1754.052	68.66677	1754.052	69.00391	0.3	0.34	0.34			
1759.942	68.69657	1759.942	68.9113	0.2	0.21	0.21			
1765.832	68.63582	1765.832	68.95116	0.3	0.32	0.32			
1771.721	68.44891	1771.721	69.08663	0.6	0.64	0.64			
1777.611	68.59001	1777.611	69.04925	0.5	0.46	0.46			
1783.501	67.8511	1783.501	69.00069	1.1	1.15	1.15			
1789.391	67.98173	1789.391	68.96571	1.0	0.98	0.98			
1795.281	68.37633	1795.281	69.13043	0.8	0.75	0.75			
1801.171	68.42728	1801.171	69.18376	0.8	0.76	0.76			
1806.937	68.43757	1806.937	69.06666	0.6	0.63	0.63			
1812.704	68.38422	1812.704	69.09983	0.7	0.72	0.72			
1818.47	68.57214	1818.47	69.27848	0.7	0.71	0.71			
1824.237	69.1733	1824.237	69.14953	0.0	-0.02	0.00			
1830.003	69.11847	1830.003	69.21396	0.1	0.10	0.10			
1835.769	68.87533	1835.769	69.2766	0.4	0.40	0.40			
1841.536	68.61988	1841.536	69.28432	0.7	0.66	0.66			
1847.302	68.27503	1847.302	69.25574	1.0	0.98	0.98			
1853.068	68.10649	1853.068	69.26124	1.2	1.15	1.15			
1858.835	68.37071	1858.835	69.19273	0.8	0.82	0.82			
1864.601	68.01466	1864.601	69.21633	1.2	1.20	1.20			
1870.367	67.90519	1870.367	69.25743	1.4	1.35	1.35			
1876.134	67.96654	1876.134	69.14905	1.2	1.18	1.18			
1881.9	68.24229	1881.9	69.04172	0.8	0.80	0.80			
1887.666	68.36652	1887.666	69.04468	0.7	0.68	0.68			
1893.433	68.56389	1893.433	69.08908	0.5	0.53	0.53			
1899.199	68.93201	1899.199	68.78179	-0.2	-0.15	0.00	303.0	0.6	for ~ 300 feet the road bed is higher than adjacent grade and we will excavate on average 0.6 feet.
1904.965	69.10294	1904.965	69.15661	0.1	0.05	0.05			
1910.732	69.18967	1910.732	69.21379	0.0	0.02	0.02			
1916.498	69.10292	1916.498	69.08582	0.0	-0.02	0.00			
1922.264	69.35023	1922.264	69.09112	-0.3	-0.26	0.00			
1928.031	70.31313	1928.031	69.07935	-1.2	-1.23	0.00			
1933.797	70.26894	1933.797	69.19735	-1.1	-1.07	0.00			
1939.563	70.42984	1939.563	69.16455	-1.3	-1.27	0.00			
1945.33	70.2393	1945.33	69.21565	-1.0	-1.02	0.00			
1951.215	70.23631	1951.215	69.28498	-1.0	-0.95	0.00			

1957.101	70.216	1957.101	69.25659	-1.0	-0.96	0.00
1962.986	70.18471	1962.986	69.42793	-0.8	-0.76	0.00
1968.871	69.97017	1968.871	69.33696	-0.6	-0.63	0.00
1974.757	69.6815	1974.757	69.21551	-0.5	-0.47	0.00
1980.642	69.94981	1980.642	69.3095	-0.6	-0.64	0.00
1986.528	70.04022	1986.528	69.28756	-0.8	-0.75	0.00
1992.413	70.2727	1992.413	69.12194	-1.2	-1.15	0.00
1998.298	70.17047	1998.298	69.09062	-1.1	-1.08	0.00
2004.184	70.03944	2004.184	68.96713	-1.1	-1.07	0.00
2010.069	70.09783	2010.069	69.02183	-1.1	-1.08	0.00
2015.955	70.13192	2015.955	69.11343	-1.0	-1.02	0.00
2021.84	69.56503	2021.84	69.12121	-0.4	-0.44	0.00
2027.725	69.08693	2027.725	69.0756	0.0	-0.01	0.00
2033.611	69.25794	2033.611	69.05756	-0.2	-0.20	0.00
2039.496	69.7805	2039.496	69.0348	-0.7	-0.75	0.00
2045.381	70.23818	2045.381	68.99651	-1.2	-1.24	0.00
2051.267	69.85131	2051.267	68.92834	-0.9	-0.92	0.00
2057.152	69.55379	2057.152	68.99278	-0.6	-0.56	0.00
2063.038	69.70581	2063.038	68.80168	-0.9	-0.90	0.00
2068.783	69.60907	2068.783	68.72971	-0.9	-0.88	0.00
2074.529	69.54425	2074.529	68.77014	-0.8	-0.77	0.00
2080.274	69.45092	2080.274	68.74348	-0.7	-0.71	0.00
2086.02	69.36397	2086.02	68.66095	-0.7	-0.70	0.00
2091.765	69.17802	2091.765	68.54206	-0.6	-0.64	0.00
2097.511	69.17608	2097.511	68.52835	-0.6	-0.65	0.00
2103.256	69.18519	2103.256	68.52692	-0.7	-0.66	0.00
2109.002	69.01075	2109.002	68.62091	-0.4	-0.39	0.00
2114.747	68.75294	2114.747	68.58006	-0.2	-0.17	0.00
2120.493	68.82329	2120.493	68.51484	-0.3	-0.31	0.00
2126.238	69.02001	2126.238	68.47932	-0.5	-0.54	0.00
2131.984	69.11805	2131.984	68.3584	-0.8	-0.76	0.00
2137.175	68.90167	2137.175	68.42089	-0.5	-0.48	0.00
2142.366	68.7105	2142.366	68.38681	-0.3	-0.32	0.00
2147.557	68.54647	2147.557	68.30932	-0.2	-0.24	0.00
2152.748	68.80418	2152.748	68.36586	-0.4	-0.44	0.00
2157.939	68.79698	2157.939	68.19968	-0.6	-0.60	0.00
2163.13	68.65628	2163.13	68.12509	-0.5	-0.53	0.00
2168.321	68.59579	2168.321	68.2557	-0.3	-0.34	0.00
2174.315	68.52323	2174.315	68.23509	-0.3	-0.29	0.00
2180.308	68.6855	2180.308	68.29343	-0.4	-0.39	0.00
2186.302	68.77189	2186.302	68.34249	-0.4	-0.43	0.00
2192.295	68.83965	2192.295	68.38583	-0.5	-0.45	0.00
2198.289	69.09164	2198.289	68.21502	-0.9	-0.88	0.00
2204.283	68.77806	2204.283	68.1284	-0.6	-0.65	0.00
2210.276	68.48034	2210.276	68.12056	-0.4	-0.36	0.00
2216.179	68.5523	2216.179	68.18225	-0.4	-0.37	0.00
2222.081	68.44574	2222.081	68.01122	-0.4	-0.43	0.00
2227.984	68.5099	2227.984	67.82524	-0.7	-0.68	0.00
2233.886	68.5712	2233.886	67.85753	-0.7	-0.71	0.00
2239.789	68.30845	2239.789	68.00852	-0.3	-0.30	0.00
2245.691	68.78427	2245.691	68.02894	-0.8	-0.76	0.00
2251.594	68.77263	2251.594	68.05478	-0.7	-0.72	0.00
2257.496	68.64046	2257.496	68.01002	-0.6	-0.63	0.00
2263.399	68.53053	2263.399	67.93359	-0.6	-0.60	0.00
2269.301	68.64604	2269.301	67.89523	-0.8	-0.75	0.00
2275.203	68.22998	2275.203	67.8009	-0.4	-0.43	0.00
2281.106	68.23102	2281.106	67.64062	-0.6	-0.59	0.00
2287.008	69.53928	2287.008	67.80177	-1.7	-1.74	0.00
2292.863	69.42273	2292.863	67.95832	-1.5	-1.46	0.00
2298.718	69.64642	2298.718	67.95282	-1.7	-1.69	0.00
2304.573	69.83447	2304.573	67.89233	-1.9	-1.94	0.00
2310.428	69.62722	2310.428	67.83022	-1.8	-1.80	0.00
2316.282	68.90296	2316.282	67.73075	-1.2	-1.17	0.00
2322.137	68.10276	2322.137	67.77807	-0.3	-0.32	0.00
2327.992	67.77918	2327.992	67.9426	0.2	0.16	0.16
2333.847	67.59263	2333.847	68.28966	0.7	0.70	0.70
2339.702	67.41227	2339.702	68.27653	0.9	0.86	0.86
2345.556	67.97385	2345.556	68.30825	0.3	0.33	0.33
2351.411	68.35834	2351.411	67.86581	-0.5	-0.49	0.00
2357.266	68.32649	2357.266	67.92779	-0.4	-0.40	0.00
2363.121	68.2712	2363.121	67.99815	-0.3	-0.27	0.00
2368.975	67.89564	2368.975	67.91781	0.0	0.02	0.02
2374.83	67.81087	2374.83	67.75546	-0.1	-0.06	0.00
2380.685	68.04218	2380.685	67.67005	-0.4	-0.37	0.00
2386.54	68.20857	2386.54	67.70459	-0.5	-0.50	0.00
2392.395	68.04138	2392.395	67.67952	-0.4	-0.36	0.00
2398.249	67.83701	2398.249	67.62318	-0.2	-0.21	0.00
2404.104	67.73105	2404.104	67.73907	0.0	0.01	0.01
2409.959	67.79992	2409.959	67.51117	-0.3	-0.29	0.00
2415.814	67.77612	2415.814	67.49805	-0.3	-0.28	0.00
2421.669	67.96265	2421.669	67.47039	-0.5	-0.49	0.00
2427.523	68.27234	2427.523	67.37908	-0.9	-0.89	0.00
2433.378	67.92928	2433.378	67.35271	-0.6	-0.58	0.00
2439.233	67.67574	2439.233	67.36816	-0.3	-0.31	0.00
2445.088	67.40425	2445.088	67.40655	0.0	0.00	0.00
2450.942	67.68507	2450.942	67.35053	-0.3	-0.33	0.00
2456.797	68.38045	2456.797	67.34396	-1.0	-1.04	0.00
2462.652	68.59315	2462.652	67.24339	-1.3	-1.35	0.00
2468.326	68.36119	2468.326	67.29893	-1.1	-1.06	0.00

2474	68.60714	2474	67.25842	-1.3	-1.35	0.00
2479.674	68.48515	2479.674	67.22397	-1.3	-1.26	0.00
2485.348	68.43735	2485.348	67.24457	-1.2	-1.19	0.00
2491.022	68.35542	2491.022	67.23355	-1.1	-1.12	0.00
2496.697	68.21736	2496.697	67.22497	-1.0	-0.99	0.00
2502.371	68.23037	2502.371	67.35181	-0.9	-0.88	0.00
2508.045	68.44402	2508.045	67.28103	-1.2	-1.16	0.00
2513.719	68.93256	2513.719	67.16985	-1.8	-1.76	0.00
2519.393	68.90355	2519.393	67.22083	-1.7	-1.68	0.00
2525.178	68.96846	2525.178	67.22413	-1.7	-1.74	0.00
2530.962	68.70992	2530.962	67.29022	-1.4	-1.42	0.00
2536.747	68.45283	2536.747	67.28305	-1.2	-1.17	0.00
2542.532	68.27988	2542.532	67.25398	-1.0	-1.03	0.00
2548.317	67.94658	2548.317	67.34784	-0.6	-0.60	0.00
2554.101	67.72941	2554.101	67.37587	-0.4	-0.35	0.00
2559.886	67.99268	2559.886	67.25708	-0.7	-0.74	0.00
2565.671	67.95313	2565.671	67.23287	-0.7	-0.72	0.00
2571.455	67.83361	2571.455	67.18244	-0.7	-0.65	0.00
2577.24	67.62329	2577.24	66.97563	-0.6	-0.65	0.00
2583.025	68.0905	2583.025	67.0033	-1.1	-1.09	0.00
2588.81	68.46135	2588.81	66.91348	-1.5	-1.55	0.00
2594.781	68.58833	2594.781	66.82676	-1.8	-1.76	0.00
2600.753	68.43265	2600.753	66.7944	-1.6	-1.64	0.00
2606.725	68.29256	2606.725	66.8289	-1.5	-1.46	0.00
2612.696	67.96105	2612.696	66.81645	-1.1	-1.14	0.00
2618.668	67.40147	2618.668	66.74539	-0.7	-0.66	0.00
2624.64	67.30683	2624.64	66.58046	-0.7	-0.73	0.00
2630.611	67.30646	2630.611	66.60698	-0.7	-0.70	0.00
2636.583	67.54635	2636.583	66.5743	-1.0	-0.97	0.00
2642.555	67.45418	2642.555	66.46593	-1.0	-0.99	0.00
2648.526	67.71484	2648.526	66.42691	-1.3	-1.29	0.00
2654.498	67.90753	2654.498	66.43865	-1.5	-1.47	0.00
2660.47	67.48483	2660.47	66.38157	-1.1	-1.10	0.00
2666.441	67.07853	2666.441	66.12419	-1.0	-0.95	0.00
2672.037	66.80768	2672.037	66.16101	-0.6	-0.65	0.00
2677.633	66.76288	2677.633	66.24676	-0.5	-0.52	0.00
2683.229	66.7708	2683.229	66.21492	-0.6	-0.56	0.00
2688.824	66.73892	2688.824	66.13154	-0.6	-0.61	0.00
2694.42	66.89045	2694.42	66.11878	-0.8	-0.77	0.00
2700.016	67.18491	2700.016	66.16188	-1.0	-1.02	0.00
2705.612	66.62084	2705.612	66.10764	-0.5	-0.51	0.00
2711.207	67.00773	2711.207	65.98479	-1.0	-1.02	0.00
2716.803	67.51065	2716.803	66.01127	-1.5	-1.50	0.00
2722.399	66.93134	2722.399	65.90789	-1.0	-1.02	0.00
2727.995	66.40327	2727.995	65.74246	-0.7	-0.66	0.00
2733.59	66.33046	2733.59	65.72568	-0.6	-0.60	0.00
2739.186	66.39479	2739.186	65.68727	-0.7	-0.71	0.00
2744.82	66.45046	2744.82	65.70201	-0.7	-0.75	0.00
2750.454	66.08725	2750.454	65.42887	-0.7	-0.66	0.00
2756.088	65.99337	2756.088	65.39257	-0.6	-0.60	0.00
2761.722	65.54825	2761.722	65.49843	0.0	-0.05	0.00
2767.356	65.30111	2767.356	65.37594	0.1	0.07	0.07
2772.99	65.21687	2772.99	65.29742	0.1	0.08	0.08
2778.624	65.12429	2778.624	65.29987	0.2	0.18	0.18
2784.258	65.13631	2784.258	65.26668	0.1	0.13	0.13
2789.892	65.15353	2789.892	65.35862	0.2	0.21	0.21
2795.526	65.30017	2795.526	65.24903	-0.1	-0.05	0.00
2801.16	65.22749	2801.16	65.17961	0.0	-0.05	0.00
2806.794	65.68235	2806.794	65.03321	-0.6	-0.65	0.00
2812.428	65.91752	2812.428	65.00437	-0.9	-0.91	0.00
2818.062	65.66866	2818.062	64.96075	-0.7	-0.71	0.00
2823.696	65.16315	2823.696	64.8776	-0.3	-0.29	0.00
2829.33	64.70719	2829.33	64.82584	0.1	0.12	0.12
2835.304	64.77937	2835.304	64.75548	0.0	-0.02	0.00
2841.278	65.18754	2841.278	64.69987	-0.5	-0.49	0.00
2847.252	65.22756	2847.252	64.84621	-0.4	-0.38	0.00
2853.226	65.03048	2853.226	64.72525	-0.3	-0.31	0.00
2859.2	64.90927	2859.2	64.72858	-0.2	-0.18	0.00
2865.174	64.58392	2865.174	64.75473	0.2	0.17	0.17
2871.148	64.75467	2871.148	64.71144	0.0	-0.04	0.00
2877.122	65.07808	2877.122	64.81555	-0.3	-0.26	0.00
2883.096	65.43648	2883.096	64.74278	-0.7	-0.69	0.00
2889.07	65.16728	2889.07	64.64221	-0.5	-0.53	0.00
2895.044	65.02749	2895.044	64.74715	-0.3	-0.28	0.00
2901.018	65.33374	2901.018	64.76048	-0.6	-0.57	0.00
2906.992	65.30996	2906.992	64.56774	-0.7	-0.74	0.00
2912.966	64.92237	2912.966	64.73006	-0.2	-0.19	0.00
2918.94	64.96246	2918.94	64.57312	-0.4	-0.39	0.00
2924.914	65.56297	2924.914	64.54122	-1.0	-1.02	0.00
2930.723	66.02363	2930.723	64.78627	-1.2	-1.24	0.00
2936.531	66.31434	2936.531	64.80186	-1.5	-1.51	0.00
2942.34	66.03298	2942.34	64.77241	-1.3	-1.26	0.00
2948.148	65.82959	2948.148	64.76896	-1.1	-1.06	0.00
2953.957	65.71445	2953.957	64.66368	-1.1	-1.05	0.00
2959.765	65.49637	2959.765	64.57852	-0.9	-0.92	0.00
2965.574	65.0629	2965.574	64.49019	-0.6	-0.57	0.00
2971.382	64.7127	2971.382	64.40561	-0.3	-0.31	0.00
2977.191	64.2036	2977.191	64.23968	0.0	0.04	0.04
2983	63.57746	2983	64.2663	0.7	0.69	0.69

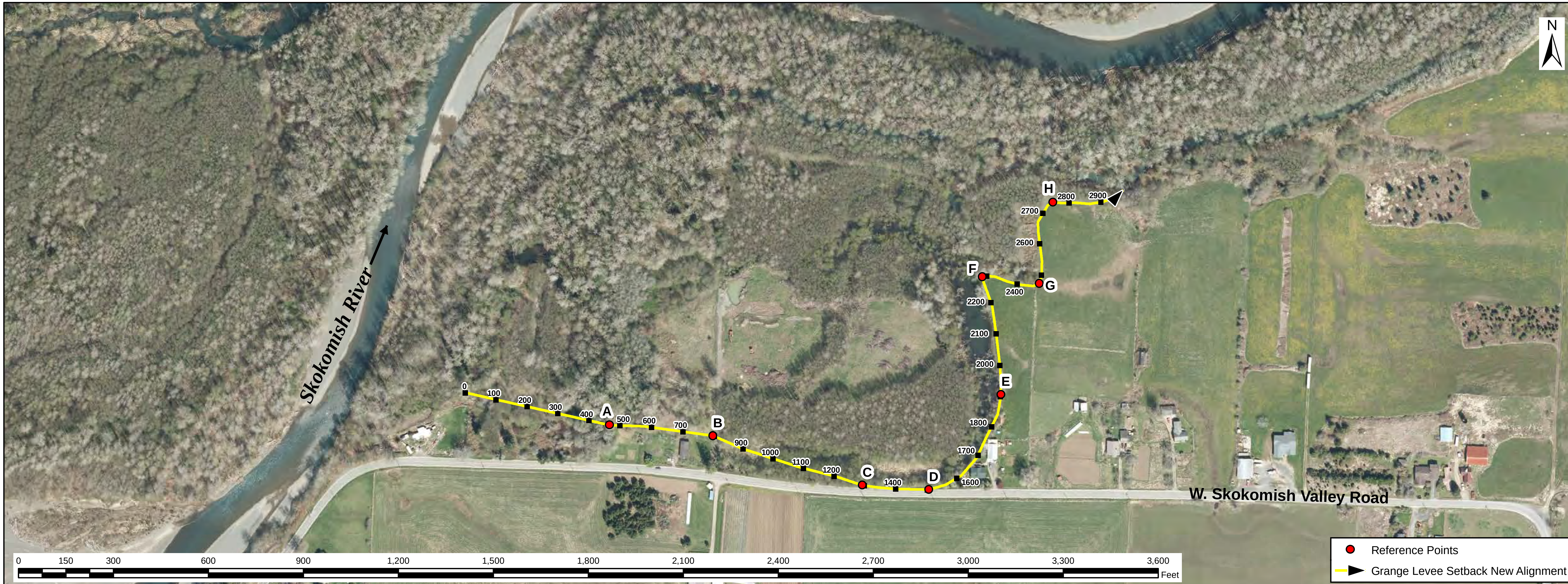
2988.808	63.22401	2988.808	64.24917	1.0	1.03	1.03		
2994.617	63.2826	2994.617	64.08314	0.8	0.80	0.80		
3000.425	63.48376	3000.425	64.1679	0.7	0.68	0.68		
3006.234	64.06754	3006.234	64.1639	0.1	0.10	0.10		
3012.042	64.79988	3012.042	64.15956	-0.6	-0.64	0.00		
3017.851	64.78343	3017.851	63.99921	-0.8	-0.78	0.00		
3023.659	64.63524	3023.659	63.99233	-0.6	-0.64	0.00		
3029.468	64.49997	3029.468	64.05338	-0.4	-0.45	0.00		
3035.277	64.33568	3035.277	64.03466	-0.3	-0.30	0.00		
3041.085	64.27533	3041.085	63.98147	-0.3	-0.29	0.00		
3046.894	64.15432	3046.894	64.0137	-0.1	-0.14	0.00		
3052.702	64.07807	3052.702	63.92905	-0.1	-0.15	0.00		
3058.511	64.16856	3058.511	63.8574	-0.3	-0.31	0.00		
3064.319	63.94409	3064.319	63.86805	-0.1	-0.08	0.00		
3070.128	63.91113	3070.128	63.82979	-0.1	-0.08	0.00		
3075.936	64.27238	3075.936	63.73056	-0.5	-0.54	0.00		
3081.745	64.06055	3081.745	63.66687	-0.4	-0.39	0.00		
3087.553	63.82245	3087.553	63.5881	-0.2	-0.23	0.00		
3093.411	63.7841	3093.411	63.47802	-0.3	-0.31	0.00		
3099.269	63.68703	3099.269	63.54478	-0.1	-0.14	0.00		
3105.127	63.76295	3105.127	63.5724	-0.2	-0.19	0.00		
3110.985	63.79615	3110.985	63.50773	-0.3	-0.29	0.00		
3116.843	63.97433	3116.843	63.53053	-0.4	-0.44	0.00		
3122.701	63.9399	3122.701	63.60629	-0.3	-0.33	0.00		
3128.559	63.82872	3128.559	63.45387	-0.4	-0.37	0.00		
3134.417	64.25447	3134.417	63.54041	-0.7	-0.71	0.00		
3140.275	64.28984	3140.275	63.41724	-0.9	-0.87	0.00		
3146.132	64.02313	3146.132	63.32133	-0.7	-0.70	0.00		
3151.99	63.8989	3151.99	63.36427	-0.5	-0.53	0.00		
3157.848	63.9157	3157.848	63.24649	-0.7	-0.67	0.00		
3163.706	63.89328	3163.706	63.19881	-0.7	-0.69	0.00		
3169.564	63.98887	3169.564	63.28357	-0.7	-0.71	0.00		
3175.422	64.10082	3175.422	63.26489	-0.8	-0.84	0.00		
3181.107	63.98559	3181.107	63.03124	-1.0	-0.95	0.00		
3186.791	63.88837	3186.791	63.08019	-0.8	-0.81	0.00		
3192.476	63.9253	3192.476	63.08058	-0.8	-0.84	0.00		
3198.16	64.04635	3198.16	63.1224	-0.9	-0.92	0.00		
3203.845	63.88821	3203.845	63.11969	-0.8	-0.77	0.00		
3209.53	63.80271	3209.53	63.22155	-0.6	-0.58	0.00		
3215.214	63.81124	3215.214	63.29803	-0.5	-0.51	0.00		
3220.899	63.6915	3220.899	63.18756	-0.5	-0.50	0.00		
3226.583	63.60581	3226.583	63.09291	-0.5	-0.51	0.00		
3232.268	63.56114	3232.268	63.1832	-0.4	-0.38	0.00		
3237.953	63.46312	3237.953	63.34101	-0.1	-0.12	0.00		
3243.637	63.58395	3243.637	63.31549	-0.3	-0.27	0.00		
3249.322	63.53762	3249.322	63.14346	-0.4	-0.39	0.00		
3255.006	63.31101	3255.006	63.15865	-0.2	-0.15	0.00		
3260.691	63.64937	3260.691	63.2087	-0.4	-0.44	0.00		
3266.376	63.82019	3266.376	63.15791	-0.7	-0.66	0.00		
3272.069	63.59137	3272.069	63.12968	-0.5	-0.46	0.00		
3277.761	63.47242	3277.761	63.0752	-0.4	-0.40	0.00		
3283.454	63.6318	3283.454	63.15654	-0.5	-0.48	0.00		
3289.147	63.55156	3289.147	63.11573	-0.4	-0.44	0.00		
3294.84	63.22788	3294.84	63.27091	0.0	0.04	0.04		
3300.533	63.38197	3300.533	63.18856	-0.2	-0.19	0.00		
3306.226	63.4232	3306.226	63.16121	-0.3	-0.26	0.00		
3311.42	63.40512	3311.42	63.15537	-0.2	-0.25	0.00		
3316.614	63.29575	3316.614	63.27406	0.0	-0.02	0.00		
3321.808	63.26757	3321.808	63.3894	0.1	0.12	0.12	1422.609	for ~ 1425 feet the roadbed is lower than existing ground remove only 0.25 asphalt.
3327.002	63.3839	3327.002	63.29916	-0.1	-0.08	0.00		
3332.196	63.27637	3332.196	63.3087	0.0	0.03	0.03		
3337.39	63.25179	3337.39	63.42083	0.2	0.17	0.17		
3342.583	63.21873	3342.583	63.46904	0.3	0.25	0.25		
3347.977	63.04069	3347.977	63.41097	0.4	0.37	0.37		
3353.37	62.95337	3353.37	63.39959	0.4	0.45	0.45		
3358.763	62.89903	3358.763	63.37036	0.5	0.47	0.47		
3364.156	62.75235	3364.156	63.48423	0.7	0.73	0.73		
3369.549	62.83054	3369.549	63.5865	0.8	0.76	0.76		
3374.942	63.09555	3374.942	63.57226	0.5	0.48	0.48		
3380.335	63.15652	3380.335	63.54088	0.4	0.38	0.38		
3385.728	63.31062	3385.728	63.576	0.3	0.27	0.27		
3391.219	63.43711	3391.219	63.77563	0.3	0.34	0.34		
3396.709	63.29539	3396.709	63.71863	0.4	0.42	0.42		
3402.199	63.24201	3402.199	63.63703	0.4	0.40	0.40		
3407.689	63.17936	3407.689	63.66253	0.5	0.48	0.48		
3413.179	63.14321	3413.179	63.93115	0.8	0.79	0.79		
3418.669	63.12824	3418.669	64.0054	0.9	0.88	0.88		
3423.947	63.0485	3423.947	64.08915	1.0	1.04	1.04		
3429.226	63.00659	3429.226	64.19844	1.2	1.19	1.19		
3434.505	63.15187	3434.505	64.2678	1.1	1.12	1.12		
3439.783	63.16574	3439.783	64.31068	1.1	1.14	1.14		
3445.062	63.1754	3445.062	64.42249	1.2	1.25	1.25		
3450.34	63.21486	3450.34	64.45104	1.2	1.24	1.24		
3456.272	63.19613	3456.272	64.52098	1.3	1.32	1.32		
3462.203	63.16824	3462.203	64.66911	1.5	1.50	1.50		
3468.135	63.17981	3468.135	64.94977	1.8	1.50	1.50		
3474.066	63.13867	3474.066	64.98903	1.9	1.50	1.50		
3479.997	63.05612	3479.997	65.07422	2.0	1.50	1.50		

3485.929	63.0158	3485.929	65.30134	2.3	1.50	1.50			
3491.86	63.04581	3491.86	65.56104	2.5	1.50	1.50			
3497.792	63.06812	3497.792	65.62715	2.6	1.50	1.50			
3503.723	62.99173	3503.723	65.6043	2.6	1.50	1.50			
3509.655	63.06981	3509.655	65.95485	2.9	1.50	1.50			
3515.586	63.00002	3515.586	66.1573	3.2	1.50	1.50			
3521.517	62.74314	3521.517	66.30702	3.6	1.50	1.50			
3527.449	62.84205	3527.449	66.43253	3.6	1.50	1.50			
3533.342	62.67718	3533.342	66.55898	3.9	1.50	1.50			
3539.236	62.627	3539.236	66.84765	4.2	1.50	1.50			
3545.129	62.72084	3545.129	66.98956	4.3	1.50	1.50			
3551.023	62.85566	3551.023	67.16456	4.3	1.50	1.50			
3556.917	63.49072	3556.917	67.42486	3.9	1.50	1.50			
3562.81	63.65389	3562.81	67.54987	3.9	1.50	1.50			
3568.704	63.763	3568.704	67.73097	4.0	1.50	1.50			
3574.597	64.88416	3574.597	67.85638	3.0	1.50	1.50			
3580.491	65.53877	3580.491	67.98405	2.4	1.50	1.50			
3586.143	65.73117	3586.143	68.22584	2.5	1.50	1.50			
3591.796	65.45884	3591.796	68.45754	3.0	1.50	1.50			
3597.448	65.50665	3597.448	68.52865	3.0	1.50	1.50			
3603.1	65.99547	3603.1	68.67365	2.7	1.50	1.50			
3608.753	65.66951	3608.753	68.85401	3.2	1.50	1.50			
3614.405	65.4918	3614.405	68.95186	3.5	1.50	1.50			
3620.057	65.68307	3620.057	69.0028	3.3	1.50	1.50			
3625.71	65.78352	3625.71	69.23877	3.5	1.50	1.50			
3631.362	65.59418	3631.362	69.42282	3.8	1.50	1.50			
3637.015	65.05153	3637.015	69.47876	4.4	1.50	1.50			
3642.633	64.66787	3642.633	69.73716	5.1	1.50	1.50			
3648.251	64.27811	3648.251	69.80279	5.5	1.50	1.50			
3653.869	63.95361	3653.869	69.99368	6.0	1.50	1.50			
3659.487	63.84157	3659.487	70.17889	6.3	1.50	1.50			
3665.106	64.1496	3665.106	70.32399	6.2	1.50	1.50			
3670.724	64.24456	3670.724	70.51491	6.3	1.50	1.50			
3676.342	64.05669	3676.342	70.5052	6.4	1.50	1.50			
3681.96	64.08441	3681.96	70.56364	6.5	1.50	1.50			
3687.578	64.0106	3687.578	70.76913	6.8	1.50	1.50			
3693.197	63.43256	3693.197	70.83363	7.4	1.50	1.50			
3698.815	62.568	3698.815	70.77196	8.2	1.50	1.50			
3704.433	61.72725	3704.433	70.44872	8.7	1.50	1.50			
3710.356	61.93691	3710.356	68.96278	7.0	1.50	1.50			
3716.279	61.31121	3716.279	66.3696	5.1	1.50	1.50			
3722.202	61.19686	3722.202	64.14144	2.9	1.50	1.50			
3728.125	62.12384	3728.125	62.86102	0.7	0.74	0.74			
3734.048	62.51581	3734.048	62.48242	0.0	-0.03	0.00			
3739.971	62.70816	3739.971	62.71487	0.0	0.01	0.01			
3745.894	62.68187	3745.894	62.17893	-0.5	-0.50	0.00			
3751.817	61.84569	3751.817	62.41707	0.6	0.57	0.57			
3757.741	61.10788	3757.741	63.07718	2.0	1.50	1.50			
3763.664	60.6176	3763.664	62.7342	2.1	1.50	1.50			
3769.587	61.38506	3769.587	61.89243	0.5	0.51	0.51			
3775.51	62.61458	3775.51	60.98887	-1.6	-1.63	0.00			
3781.433	63.06711	3781.433	60.22842	-2.8	-2.84	0.00			
3787.356	63.58798	3787.356	61.09106	-2.5	-2.50	0.00			
3793.279	64.52743	3793.279	62.7335	-1.8	-1.79	0.00			
3799.202	65.63875	3799.202	64.06991	-1.6	-1.57	0.00			
3805.125	66.07546	3805.125	66.25542	0.2	0.18	0.18			
3811.048	66.16517	3811.048	69.31844	3.2	1.50	1.50			
3816.971	65.70185	3816.971	70.49767	4.8	1.50	1.50			
3822.894	65.74695	3822.894	70.5591	4.8	1.50	1.50			
3828.817	66.01548	3828.817	70.39662	4.4	1.50	1.50			
3834.74	66.47583	3834.74	70.34454	3.9	1.50	1.50			
3840.664	66.87706	3840.664	70.41196	3.5	1.50	1.50			
3846.587	67.17885	3846.587	70.51218	3.3	1.50	1.50			
3852.51	66.97815	3852.51	70.47211	3.5	1.50	1.50			
3858.433	66.91475	3858.433	70.24209	3.3	1.50	1.50			
3864.356	66.7819	3864.356	70.23375	3.5	1.50	1.50			
3869.847	66.06435	3869.847	70.12641	4.1	1.50	1.50			
3875.337	65.21912	3875.337	69.97338	4.8	1.50	1.50			
3880.828	64.16802	3880.828	69.8902	5.7	1.50	1.50			
3886.319	63.98365	3886.319	69.78436	5.8	1.50	1.50			
3891.81	63.79697	3891.81	69.59949	5.8	1.50	1.50			
3897.3	63.72523	3897.3	69.52233	5.8	1.50	1.50			
3902.791	63.58216	3902.791	69.41528	5.8	1.50	1.50			
3908.282	63.22592	3908.282	69.19264	6.0	1.50	1.50	586.474	1.13	for ~ 585 feet the road bed is higher than adjacent grade and we will excavate on average 1.1 feet.

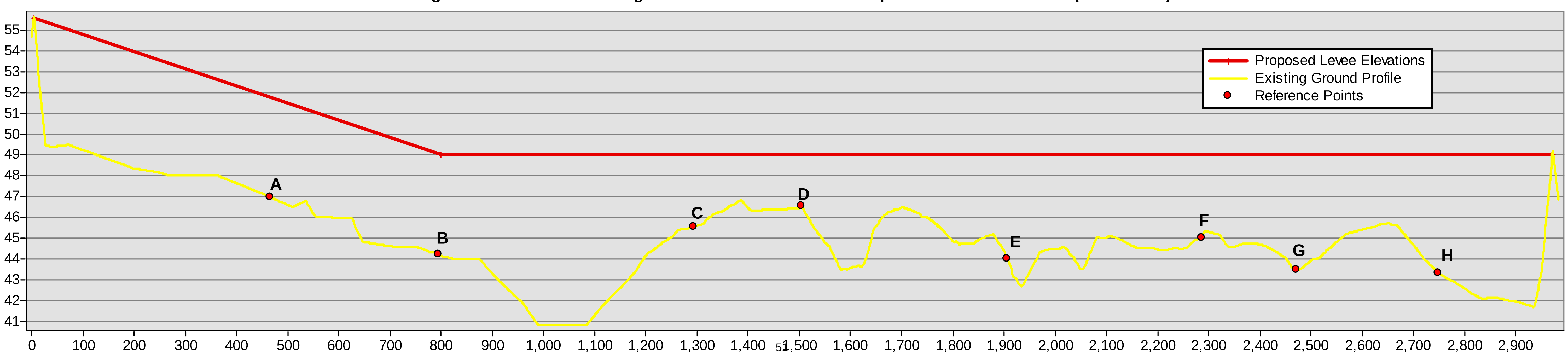
Grange Levee Setback Calculations

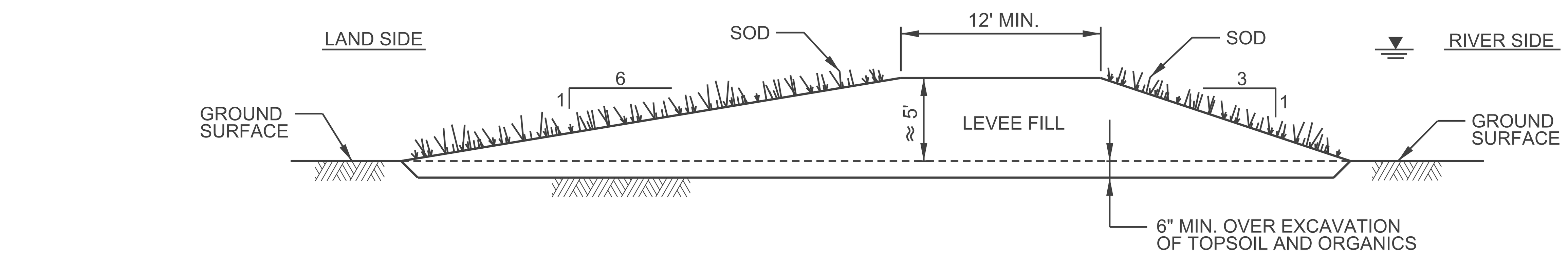
Degrade & Setback

Skokomish GI: Grange Levee Setback New Alignment Ground Profile with Proposed Levee Elevations [24SEP2013]



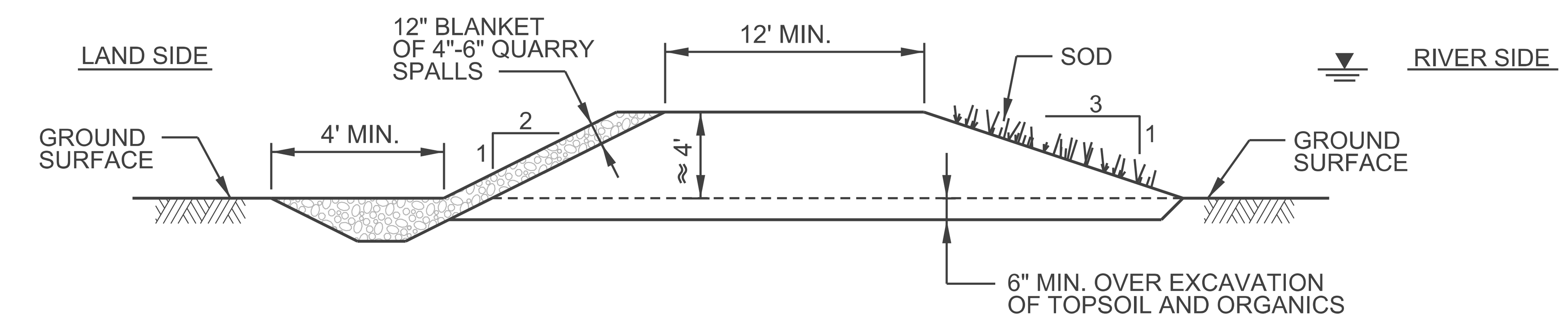
Grange Levee Setback New Alignment Ground Profile with Proposed Levee Elevations (NAVD88 FT)





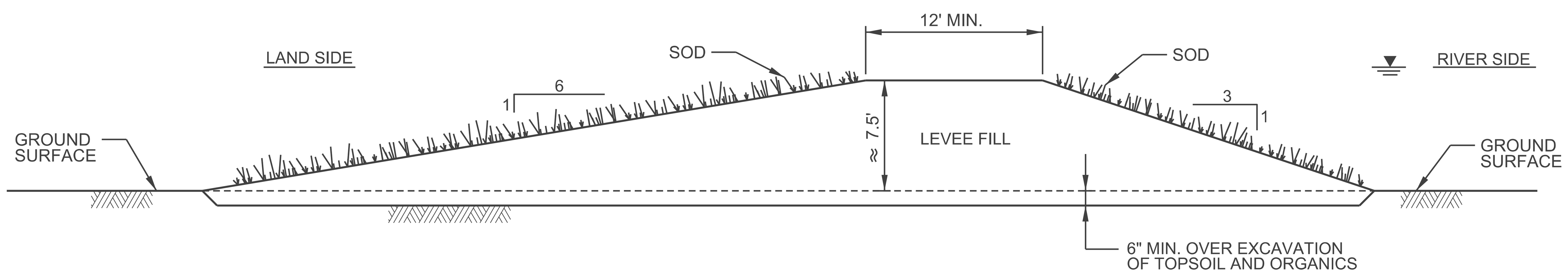
1 C-301 GRANGE LEVEE SETBACK: STA 0+00 - 9+00, 12+00 - 13+00, 19+00 - 27+00

NOT TO SCALE



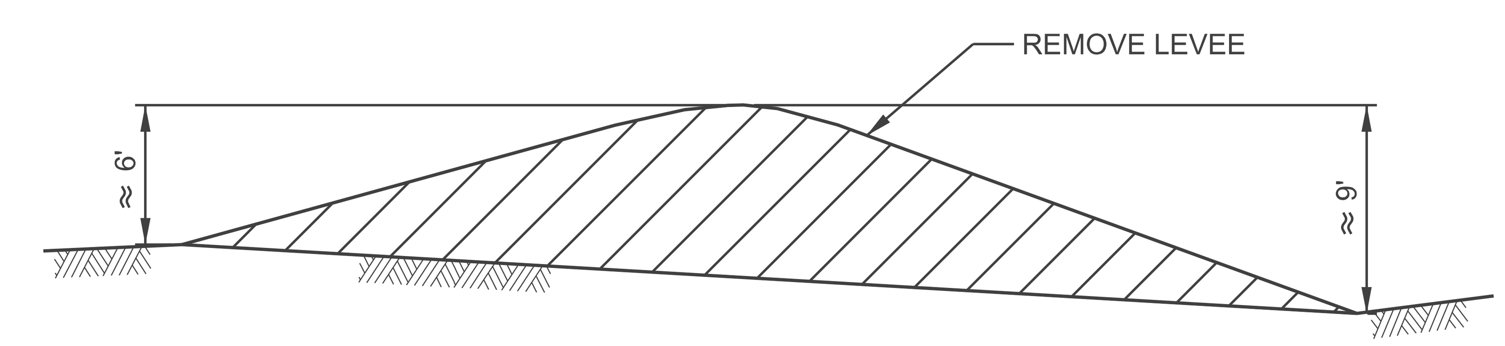
4 C-301 GRANGE LEVEE SETBACK: STA 15+00 - 19+00

NOT TO SCALE



2 C-301 GRANGE LEVEE SETBACK: STA 9+00 - 12+00, 27+00 - 30+00

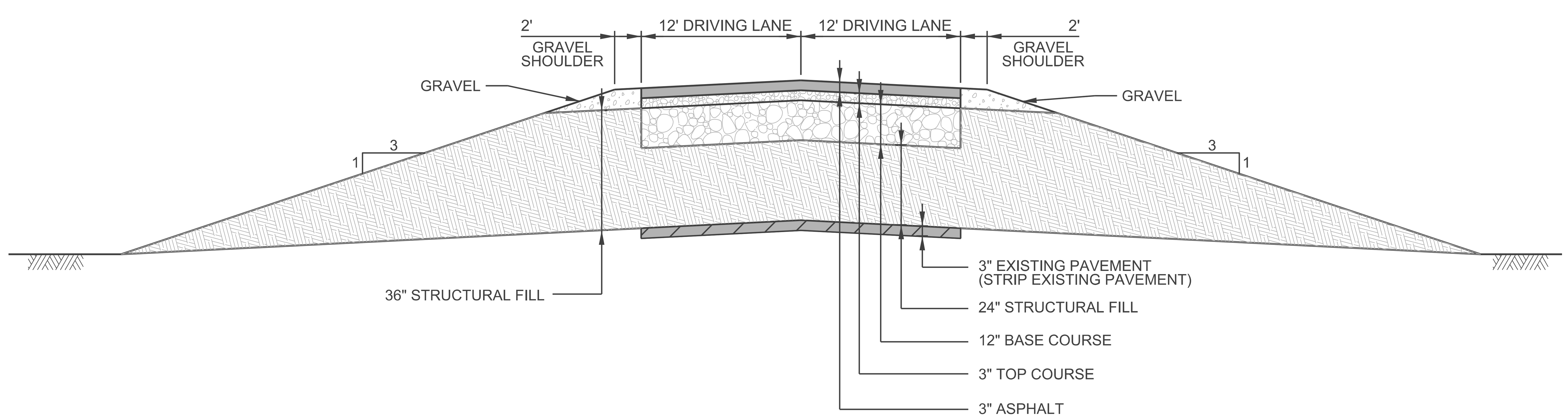
NOT TO SCALE



5 C-301 TYP DEGRADE STA: (A) 1+55-4+25, (B) 18+55-23+85

NOT TO SCALE

LEGEND	
▨	REMOVE MATERIAL



3 C-301 GRANGE LEVEE SETBACK AT SKOKOMISH VALLEY ROAD: STA 13+00 - 15+00

NOT TO SCALE

QUANTITIES DEMO	
EXISTING PAVEMENT DEMO (CY)	EXISTING GRANGE LEVEE DEGRADE (CY)
125	5,220

QUANTITIES FILL							
4"-6" QUARRY SPALL BLANKET (CY)	STRUCTURAL FILL (CY)	BASE COURSE (CY)	TOP COURSE (CY)	PAVEMENT (CY)	GRAVEL SHOULDERS (CY)	LEVEE FILL (CY)	OVER EXCAVATION ORGANICS (CY)
200	1100	500	125	125	60	23,500	3020

NOTES:

1. STRIP EXISTING PAVEMENT. ADD APPROX. 36" ADDITIONAL FILL TO RAISE ROAD TO REQUIRED ELEVATION.
2. WILL REQUIRE APPROX. 175' TRANSITIONS AT 2% SLOPE ON EAST AND WEST ENDS TO RETURN ROAD TO EXISTING ELEVATION.
3. ROAD TOTAL BASE WIDTH TO INCREASE. MAY REQUIRE ADDITIONAL RIGHT-OF-WAY.
4. SECTIONS DRAWN LOOKING UPSTREAM

US Army Corps of Engineers®
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SEATTLE DISTRICT
SEATTLE, WASHINGTON

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832

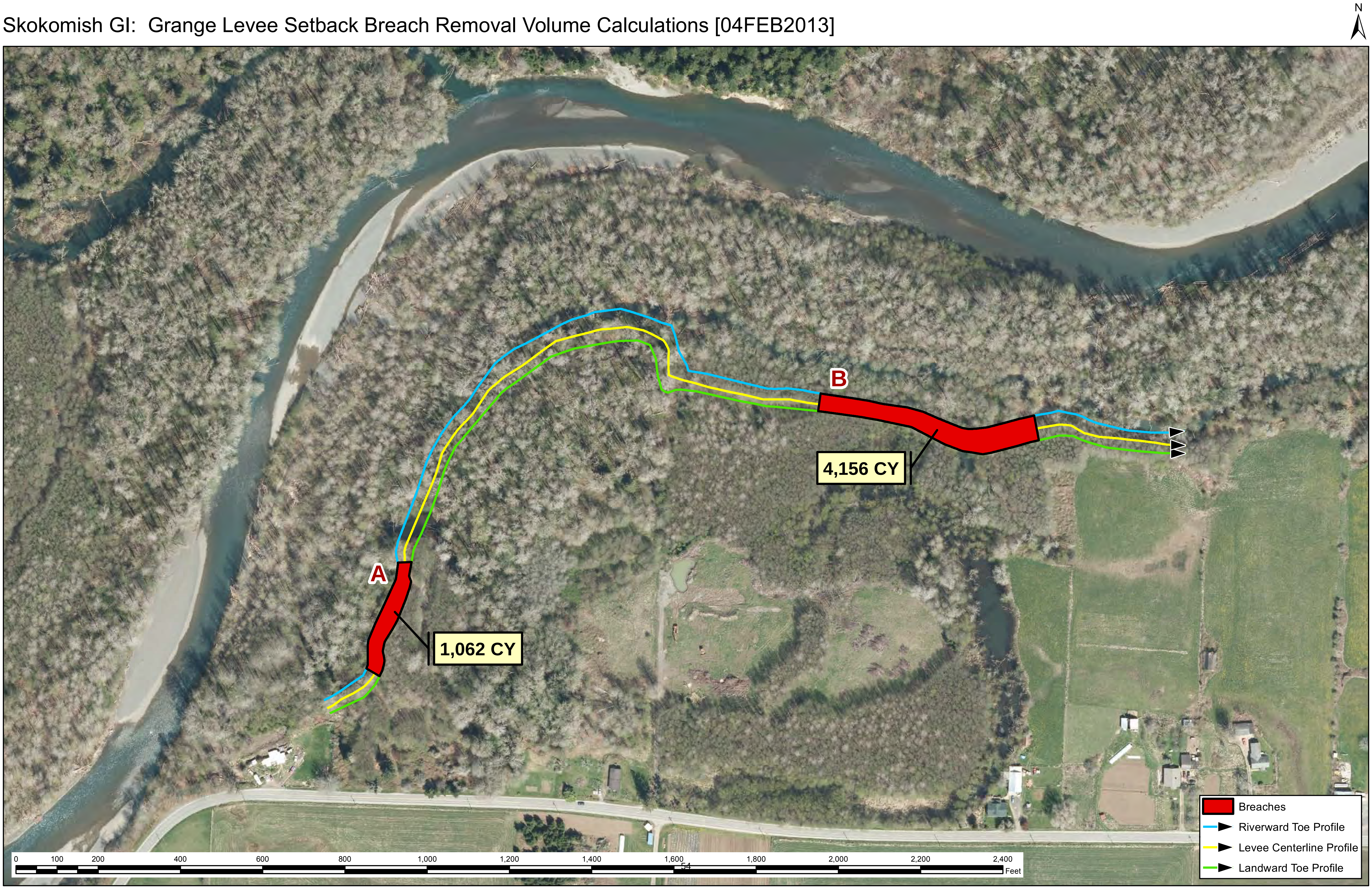
GRANGE LEVEE SETBACK

SHEET IDENTIFICATION
C-301

DATE AND TIME PLOTTED: 9/25/2013

Grange Levee Degrade Calculations

Skokomish GI: Grange Levee Setback Breach Removal Volume Calculations [04FEB2013]



SKOKOMISH GI GRANGE LEVEE SETBACK

Close agreement with GIS. Using GIS for final Volumes.

Volume CY Calculated GIS =	1062
Percent Difference from GIS=	-6%

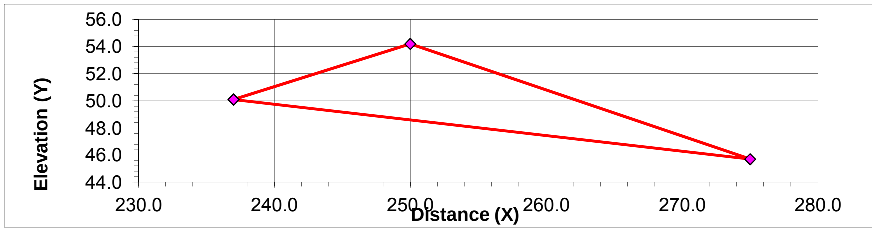
Vol. CY Upstream Breach= 1,128

Length FT Sect A Upstrm Breach =

Run A1 :		125		**End Area =**	106.50
Station : Section A				**Volume CY=**	493
X	**Y**	**X1*Y2**	**Y1*X2**		
237	50	12845.4	12525		
250	54	11425	14905		
275	46	13777.5	10830.9		
237	50	0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		38047.9	38260.9		

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.

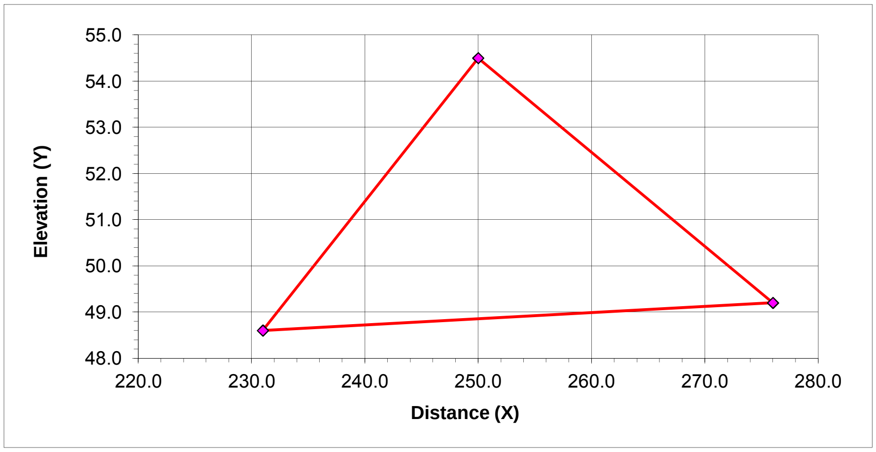


Length FT Sect B Upstrm Breach

Run B :		135		**End Area =**	127
Station : Section B				**Volume CY=**	635
X	**Y**	**X1*Y2**	**Y1*X2**		
231	48.6	12589.5	12150		
250	54.5	12300	15042		
276	49.2	13413.6	11365.2		
231	48.6	0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		38303.1	38557.2		

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.



Section C is breached in the existing condition.

Length FT Sect D Dnstrm Breach | Vol. CY Downstream Breach= 4,172

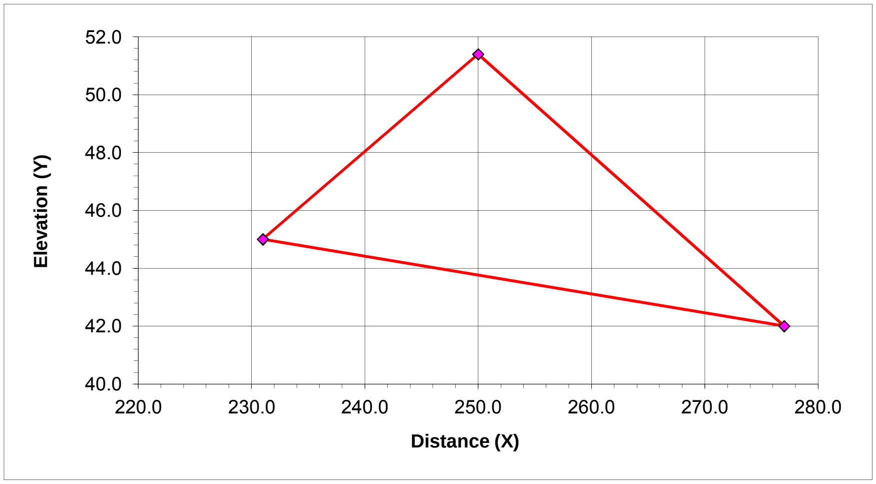
Run D :	175	End Area =	176
Station : Section C		Volume CY=	1,139

Volume CY Calculated GIS =	4156
Percent Difference from GIS=	-0.38%

X	Y	X1*Y2	Y1*X2
231	45	11873.4	11250
250	51	10500	14237.8
277	42	12465	9702
231	45	0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		34838.4	35189.8

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.



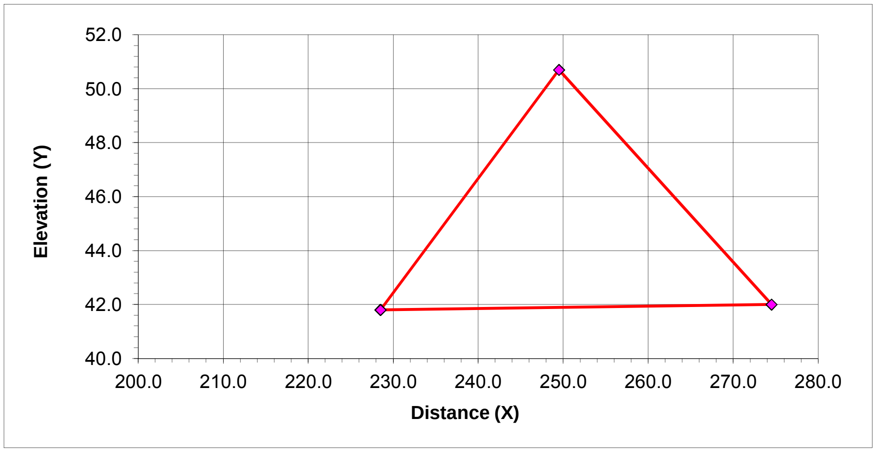
Length FT Sect E Dnstrm Breach

Run E:	175	End Area =	202.6
Station :		Volume CY=	1,313

X	Y	X1*Y2	Y1*X2
228.5	41.8	11584.95	10429.1
249.5	50.7	10479	13917.15
274.5	42	11474.1	9597
228.5	41.8	0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		33538.05	33943.25

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.



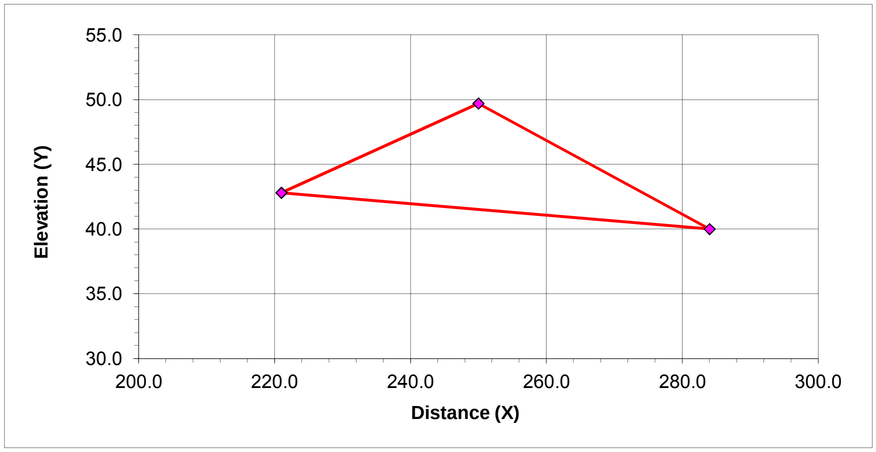
Length FT Sect F Dnstrm Breach

Run F :	180.00			**End Area =**	257.95
Station : E					1719.7

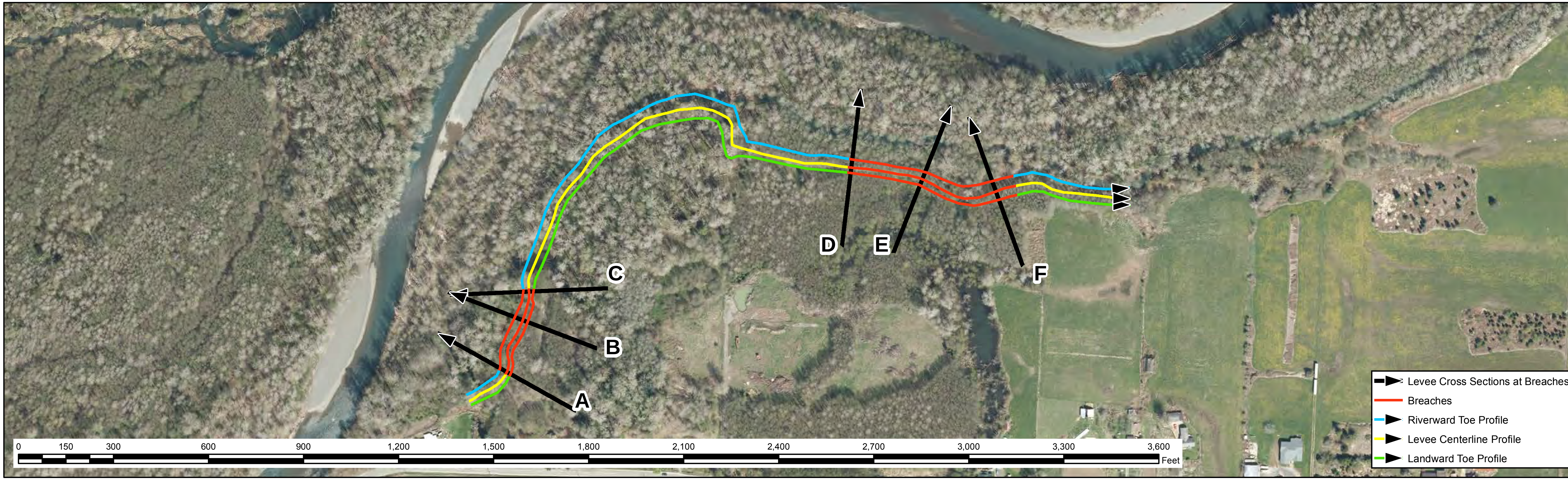
X	Y	X1*Y2	Y1*X2
221	42.8	10983.7	10700
250	50	10000	14114.8
284	40	12155.2	8840
221	42.8	0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		33138.9	33654.8

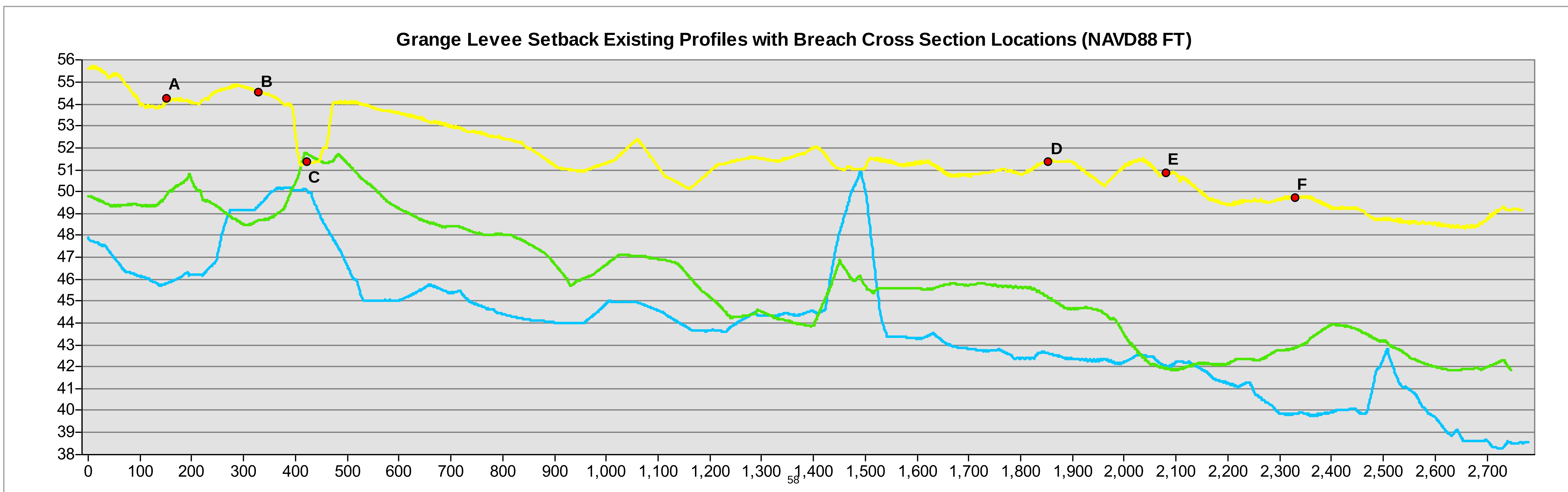
* Remember to reenter the 1st X1/Y1 as the last entry.

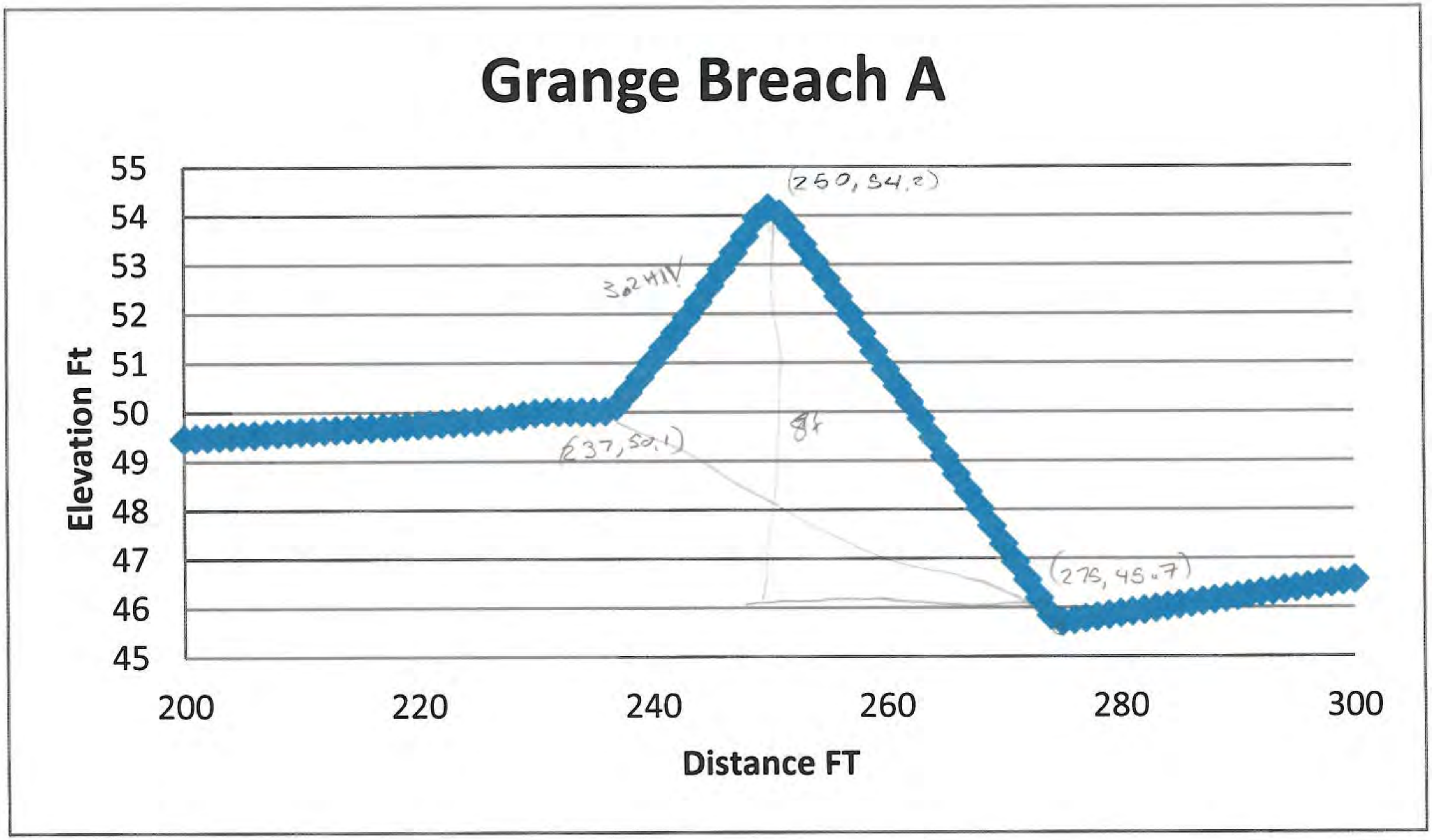
* If you have more than 16 X/Y entries just add some rows above Row 20.



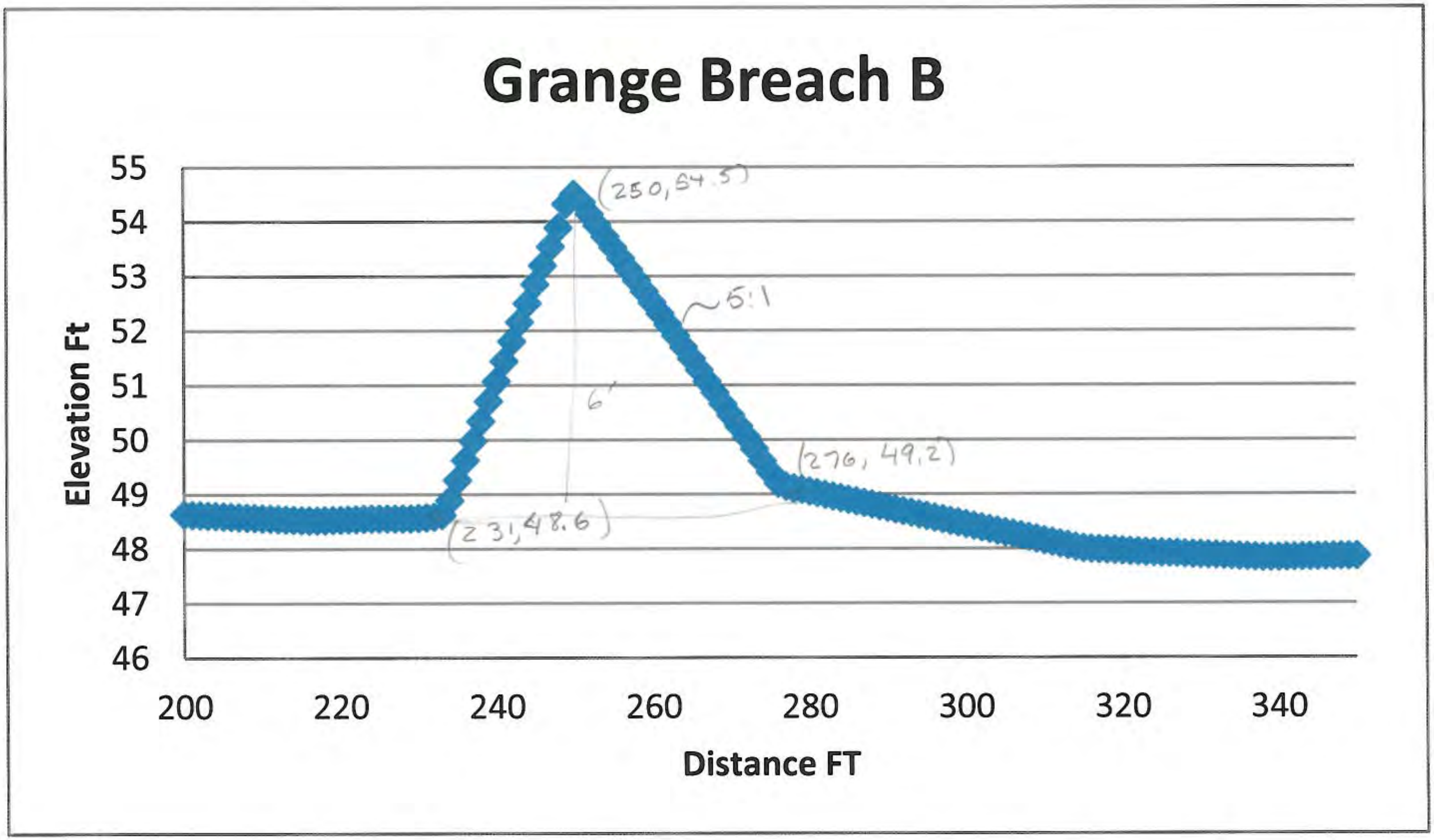
Skokomish GI: Grange Levee Setback Existing Profiles with Breach Cross Section Locations [04FEB2013]



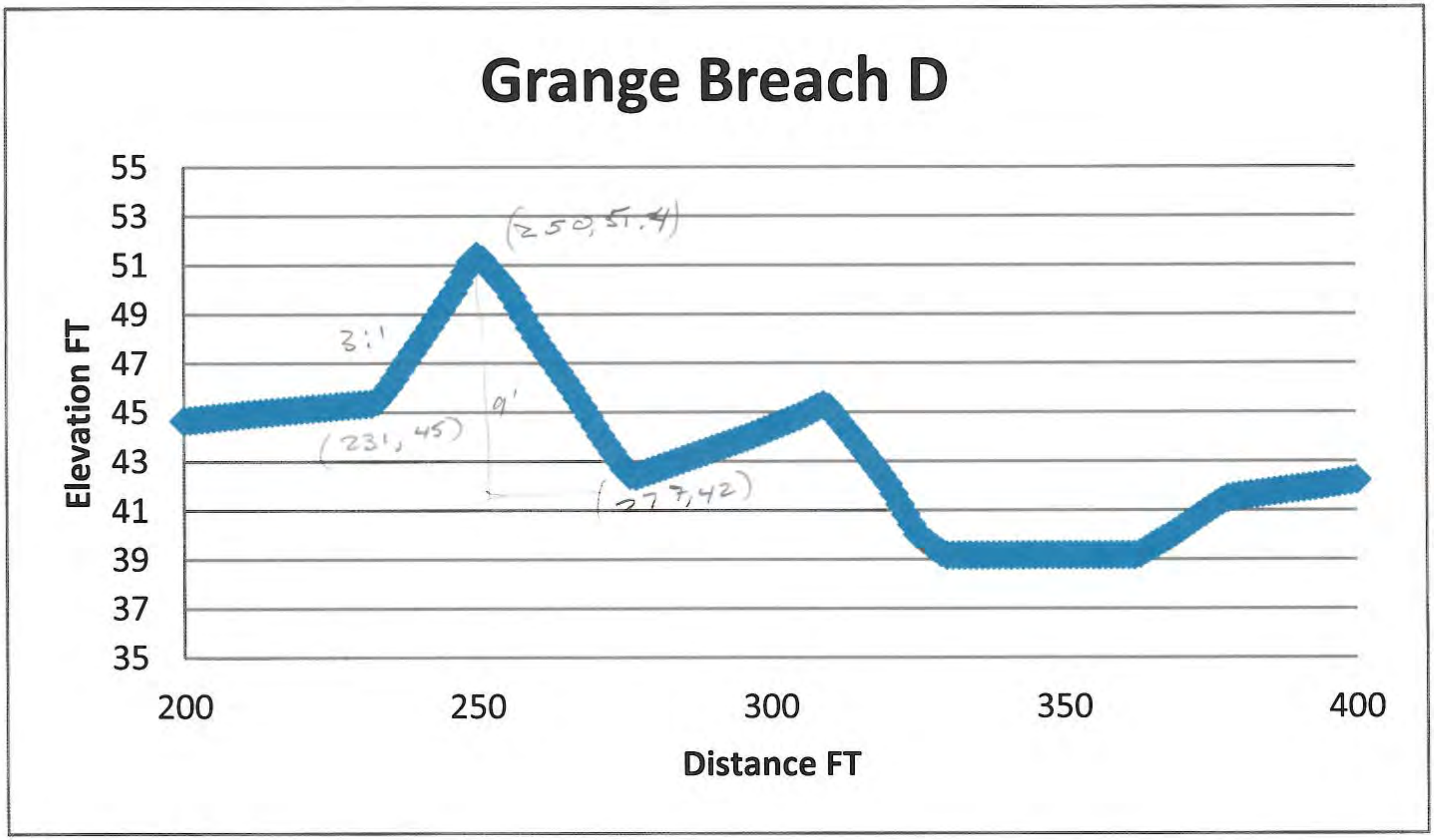




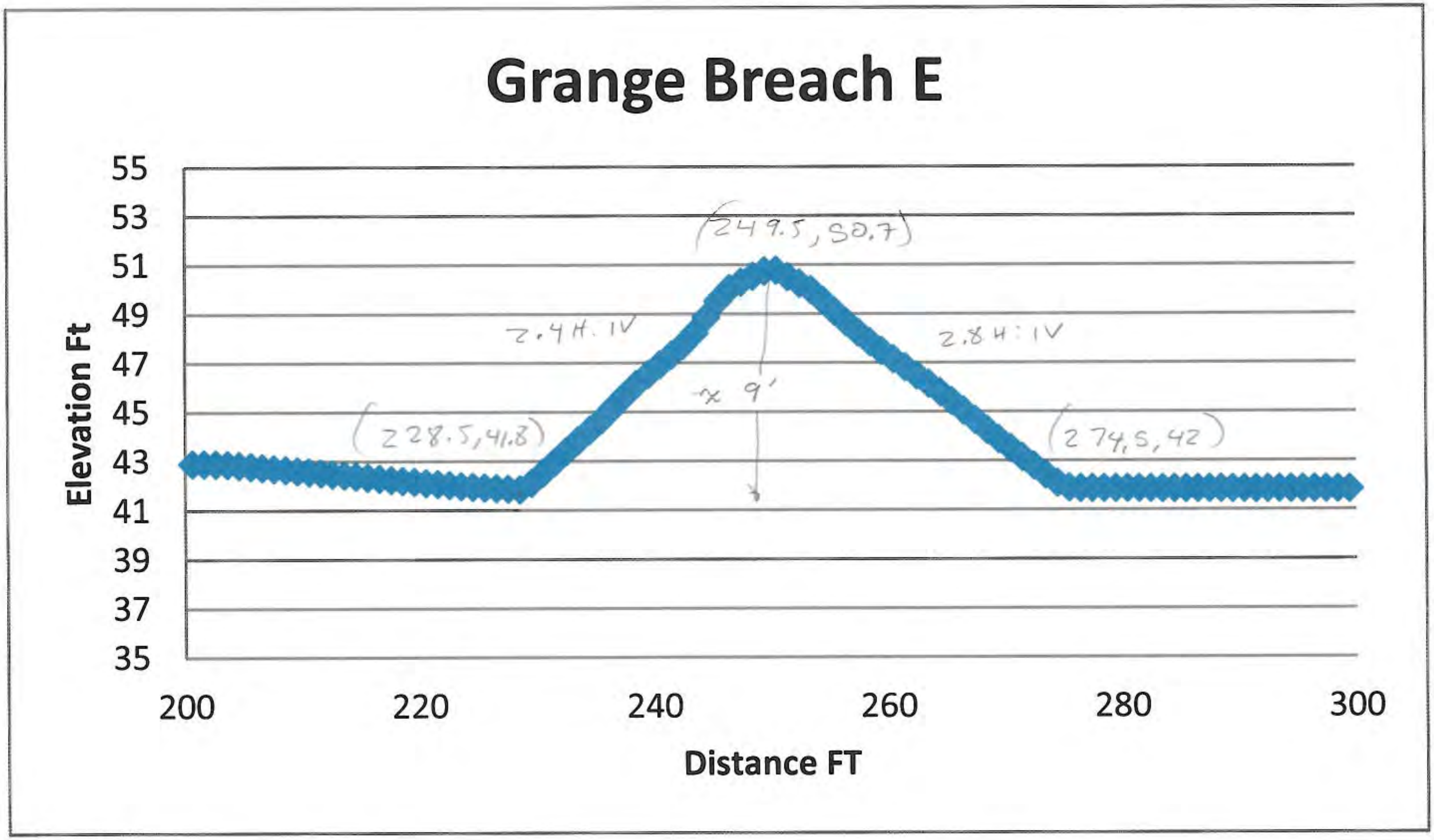
Grange Breach A
Elevation Ft
55
54
53
52
51
50
49
48
47
46
45
200
220
240
260
280
300
Distance FT
(250, 54.2)
3.2H:1V
(237, 50.1)
8ft
(275, 45.7)



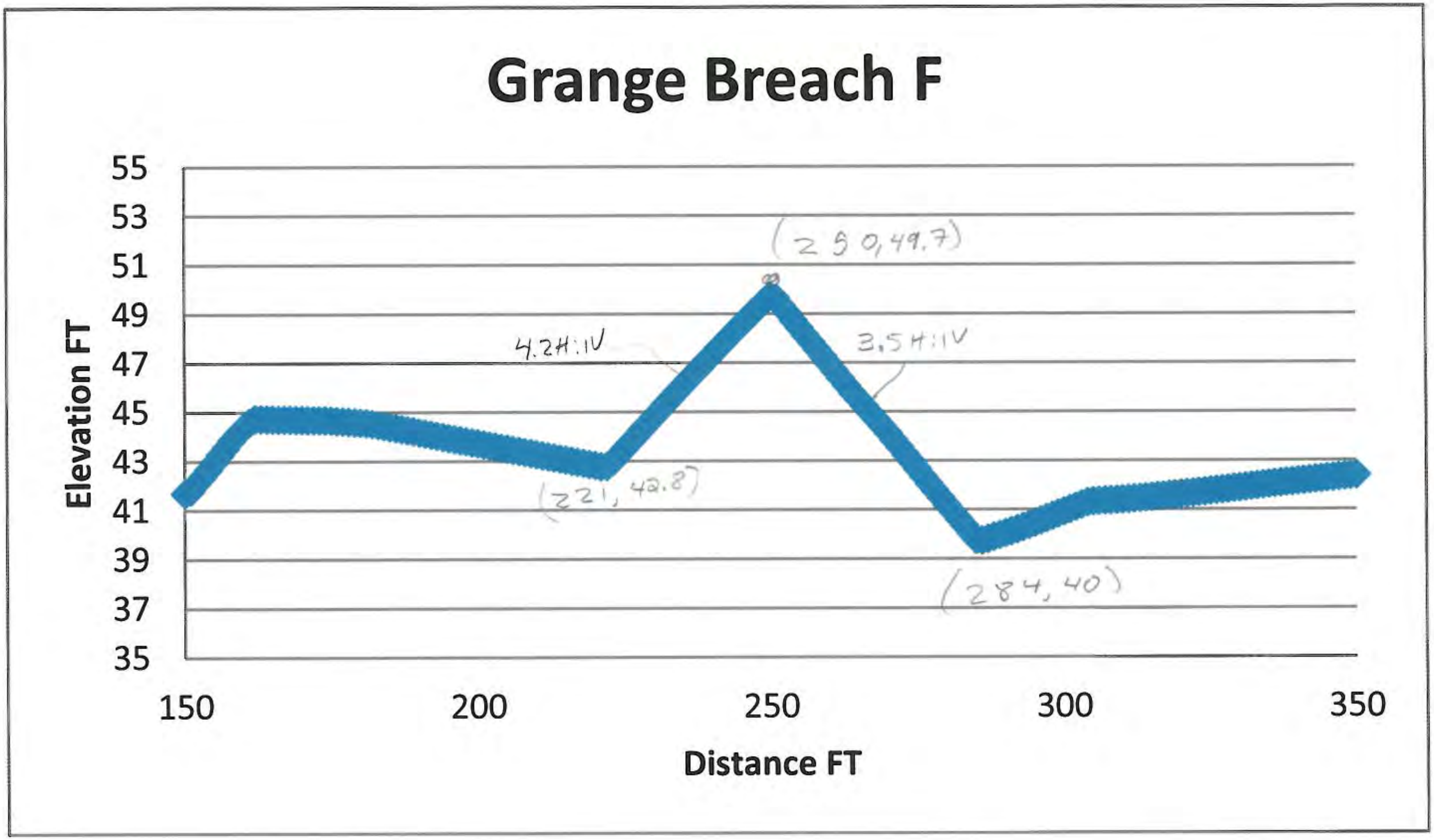
Grange Breach B
Elevation Ft
55
54
53
52
51
50
49
48
47
46
200
220
240
260
280
300
320
340
Distance FT
(250, 54.5)
~5:1
6'
(276, 49.2)
(231, 48.6)



Grange Breach D
55
53
51
49
47
45
43
41
39
37
35
Elevation FT
200
250
300
350
400
Distance FT
(250, 51.4)
3:1
9'
(231, 45)
(277, 42)

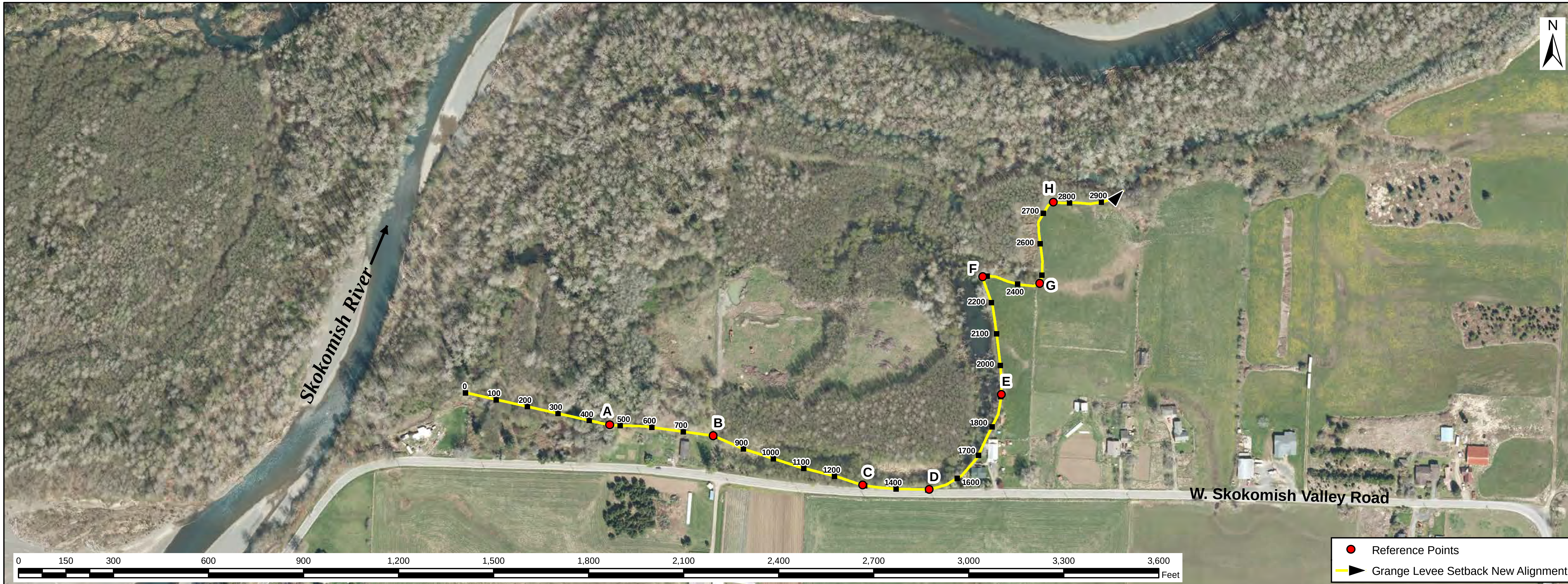


Grange Breach E
55
53
51
49
47
45
43
41
39
37
35
Elevation Ft
200
220
240
260
280
300
Distance FT
(249.5, 50.7)
2.4H.1V
2.8H:1V
≈ 9'
(228.5, 41.8)
(274.5, 42)

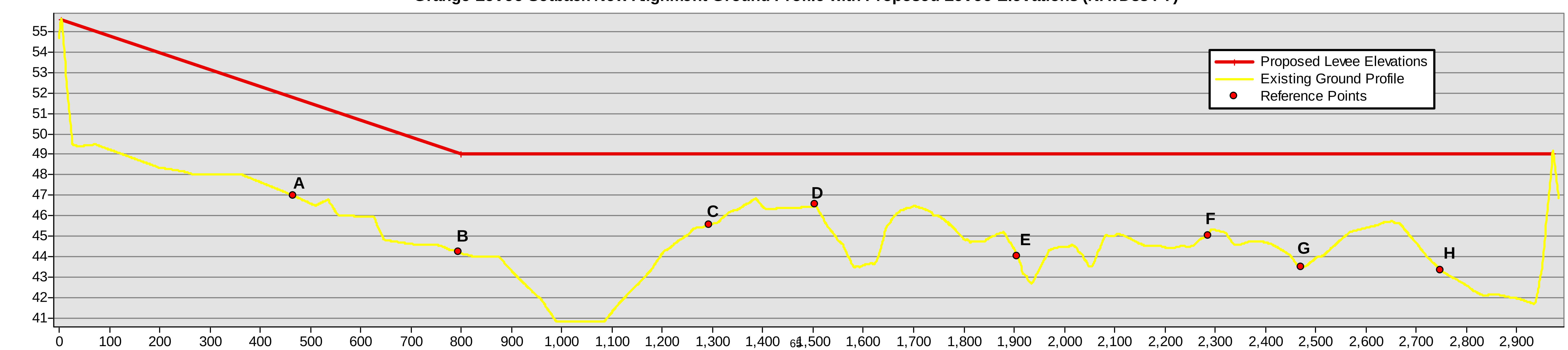

Grange Breach F
55
53
51
49
47
45
43
41
39
37
35
Elevation FT
150
200
250
300
350
Distance FT
(250,49.7)
4.2H:1V
3.5H:1V
(221, 42.8)
(284, 40)

Grange Levee Setback Calculations

Skokomish GI: Grange Levee Setback New Alignment Ground Profile with Proposed Levee Elevations [24SEP2013]



Grange Levee Setback New Alignment Ground Profile with Proposed Levee Elevations (NAVD88 FT)



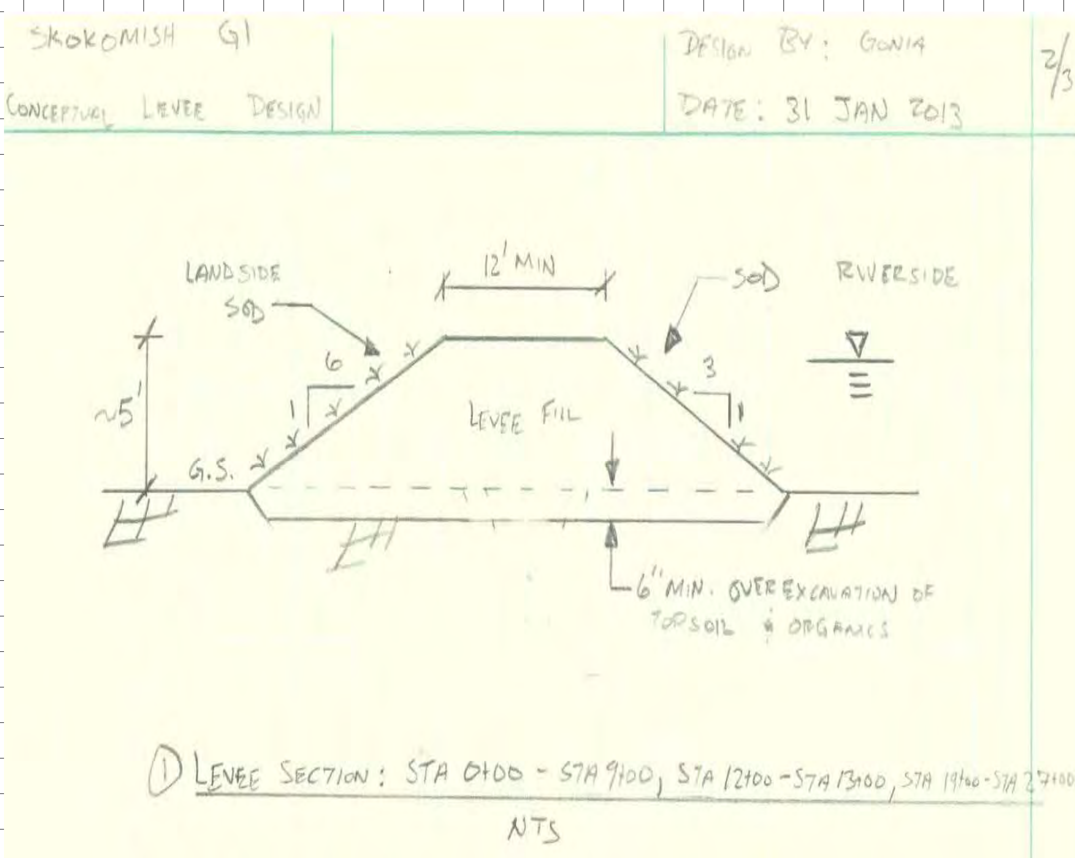
U.S. ARMY CORPS OF ENGINEERS

PROJECT: Skok River Ecosystem Rest. GI		COMPUTED BY: Rosa Radding	DATE: 15-Feb-2013
SUBJECT: Large Levee Proposed Setback		CHECKED BY:	SHT. 1 of 5

Proposed Grange Levee Set Back Section 1

Station 0+00 to 9+00, 12+00 - 13+00, 19+00-27+00

Levee Height FT Approx. FT=	5	
Crown Width FT =	12	
Side Slopes: Protected Side=	6	H:1V
Side Slopes: River Side=	3	H:1V
Depth of Overexcavation to remove Organics FT=	0.5	
Alignment length Ft	1,800	
Levee Fill SF	173	
Levee Fill CY	11,500	
Over Excavation SF	28.5	
Over Excavation CY	**1,900**	
Total Fill Over Ex + New Levee CY=	**13,400**	

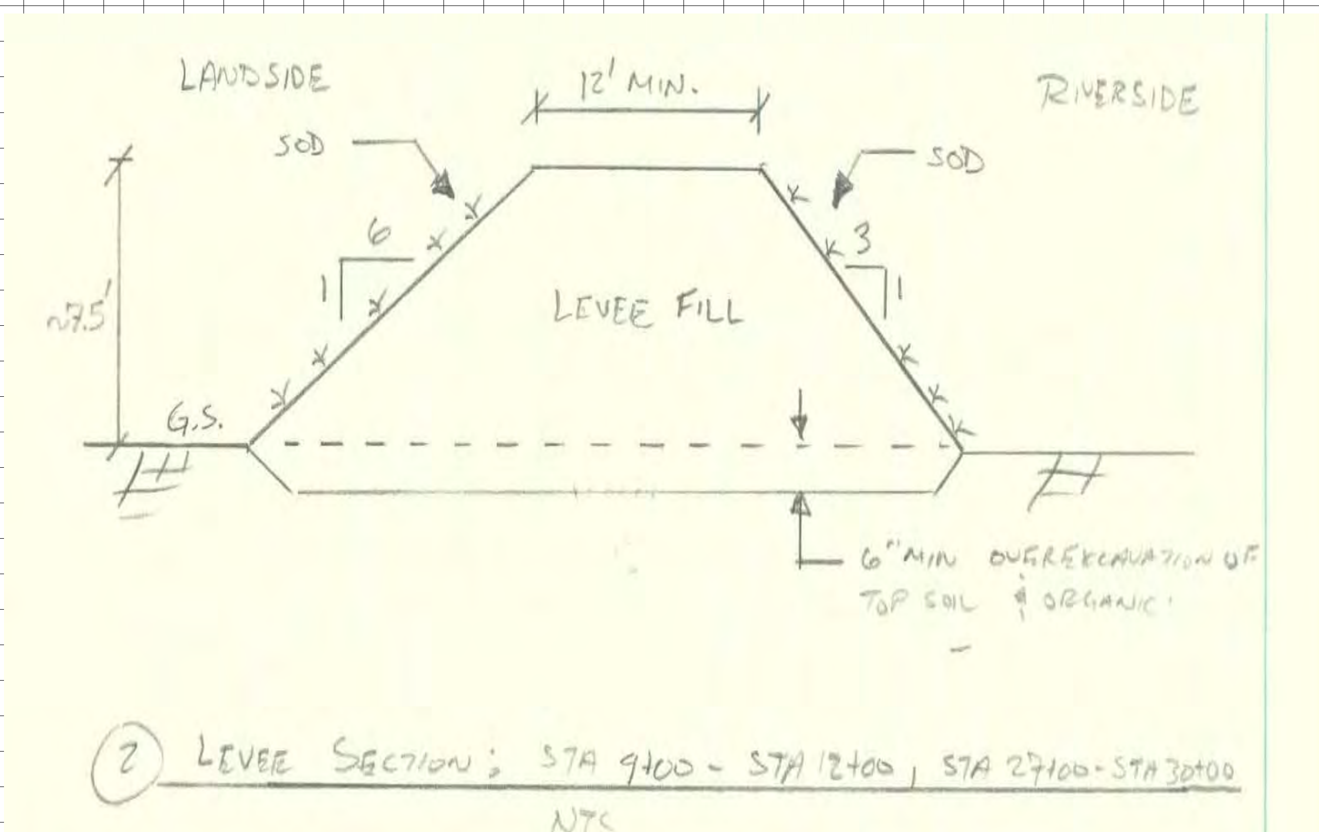


U.S. ARMY CORPS OF ENGINEERS

PROJECT: **Skok River Ecosystem Rest. GI**	COMPUTED BY: Rosa Radding	DATE: 15-Feb-2013
SUBJECT: **Grange Levee Proposed Setback**	CHECKED BY:	SHT. 2 of 5

Proposed Grange Levee Set Back Section 2

Station 9+00 to 12+00 & 27+00-30+00	
Levee Height FT Approx. FT=	7.5
Crown Width FT =	12
Side Slopes: Protected Side=	6 H:1V
Side Slopes: River Side=	3 H:1V
Depth of Overexcavation to remove Organics FT=	0.5
Alignment length Ft	600
Levee Fill SF	343.13
Levee Fill CY	7,625
Over Excavation SF	39.75
Over Excavation CY	**883**
Total Fill Over Ex + New Levee CY=	**8,508**



U.S. ARMY CORPS OF ENGINEERS

PROJECT: **Skok River Ecosystem Rest. GI**	COMPUTED BY: Rosa Radding	DATE: 15-Feb-2013
SUBJECT: **Grange Levee Proposed Setback**	CHECKED BY:	SHT. 3 of 5

Proposed Grange Levee Set Back Section 3 at Valley Road Sta 13+00-15+00

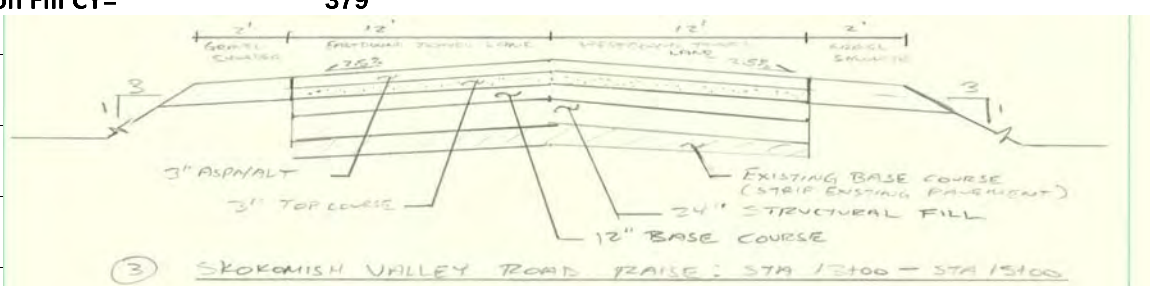
Roadway Section Length FT=	200			
Road Transitions LF=	350		Assume 175 ft transitions at 2% slope on East and West Ends to Return Road to Existing Elevation. Assume 2' Wide Gravel Shoulders 3H21V SS	
Demo Existing Pavement:				
Roadway Width FT=	24			
Pavement Thickness FT=	0.25			
Volume Existing Pavement For Demo CY=	**122**			
Vertical Change in Grade FT=	3.5			
Proposed Pavement CY=	**122**		Gravel Shoulders CY=	56
Proposed Top Course CY=	**122**			
Base Course Thickness FT=	1			
Base Course Volume CY:	**489**			

Structural Fill To Raise 200 LF Roadway

Depth of Structural Fill FT=	2		
Volume of Structual Fill below roadway section CY=	356		
Structural Fill Below Shoulders CY=	356		
Total Structural Road Section Fill CY=	**711**		

Structural Fill Along Transitions 350 LF Roadway

Assume Ave Height FT=	1.5		
Assume 0.5' Fill Below 200 LF base course			
Volume Structrual Fill Below Transitional Road Section CY=	156		
Volume Structrual Fill Below Transitional Shoulders CY=	224		
Total Structural Transition Fill CY=	**379**	**Sum Structural Fill CY =**	1090

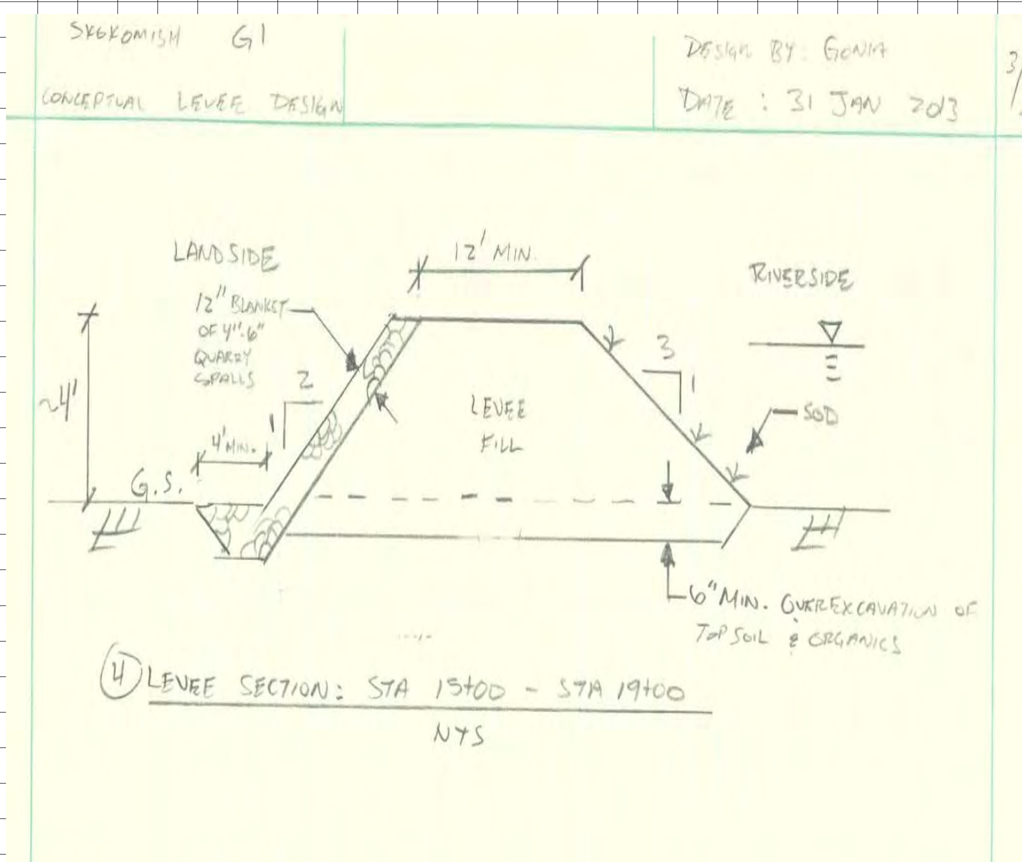


U.S. ARMY CORPS OF ENGINEERS

PROJECT: Skok River Ecosystem Rest. GI		COMPUTED BY: Rosa Radding	DATE: 15-Feb-2013
SUBJECT: Grange Levee Proposed Setback		CHECKED BY:	SHT. 4 of 5

Proposed Grange Levee Set Back Section 4

Station 15+00 to 19+00	
Levee Height FT Approx. FT=	4
Crown Width FT =	12
Side Slopes: Protected Side=	2 H:1V
Side Slopes: River Side=	3 H:1V
Depth of Overexcavation to remove Organics FT=	0.5
Alignment length Ft	400
Levee Fill SF	88
Levee Fill CY	1,304
Over Excavation SF	16
Over Excavation CY	237
Total Fill Over Ex + New Levee CY=	**1,541**
Quarry Spall Blanket CY=	**192**



U.S. ARMY CORPS OF ENGINEERS

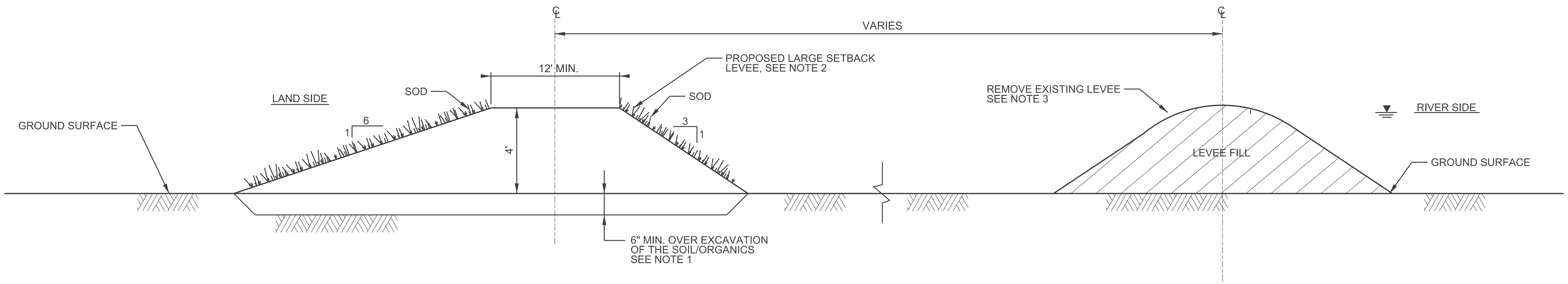
PROJECT: **Skok River Ecosystem Rest. GI**		COMPUTED BY: Rosa Radding	DATE: 15-Feb-2013
SUBJECT: **Proposed Grange Setback Levee**		CHECKED BY:	SHT.

Totals:

Demo Existing Pavement CY=	122
Proposed Pavement CY=	122
Proposed Base Course CY=	489
Proposed Top Course CY=	122
Gravel Shoulders CY=	56
Structural Fill for Roadway CY=	1,090
4-6" Quarry Spall Blanket CY=	192
Over Excavation CY=	3,020
Excavation & New Levee CY=	23,449

Large Levee Setback Calculations

Degrade & Setback



TYPICAL LARGE SETBACK LEVEE SECTION

NOT TO SCALE

NOTES:

1. OVER EXCAVATION ESTIMATED 3,300 CY.
2. LEVEE FILL VOLUME ESTIMATED 20,000 CY.
3. EXISTING LEVEE DEGRADE ESTIMATED 6,000 CY.

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CKD BY:
SUBMITTED BY:
PLOT DATE: 4/18/2013
PLOT TIME: 9:20:59 AM
SIZE: ANSI D
FILE NAME: PN60344_SKOK-C-LEVEE SECTION1.DGN
DATE: DD MONTH 2011
SOLICITATION NO.: X000XX-00-X-0002
CONTRACT NO.: X000XX-00X-0000
FILE NUMBER: E-25-1-22

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832

ALTERNATIVE 1

SHEET IDENTIFICATION
C-301
SHEET OF

DESIGN FILE: c:\users\g3ecdrd9\documents\cenws01\dms73333\PN60344_SKOK-C-LEVEE SECTION1.DGN

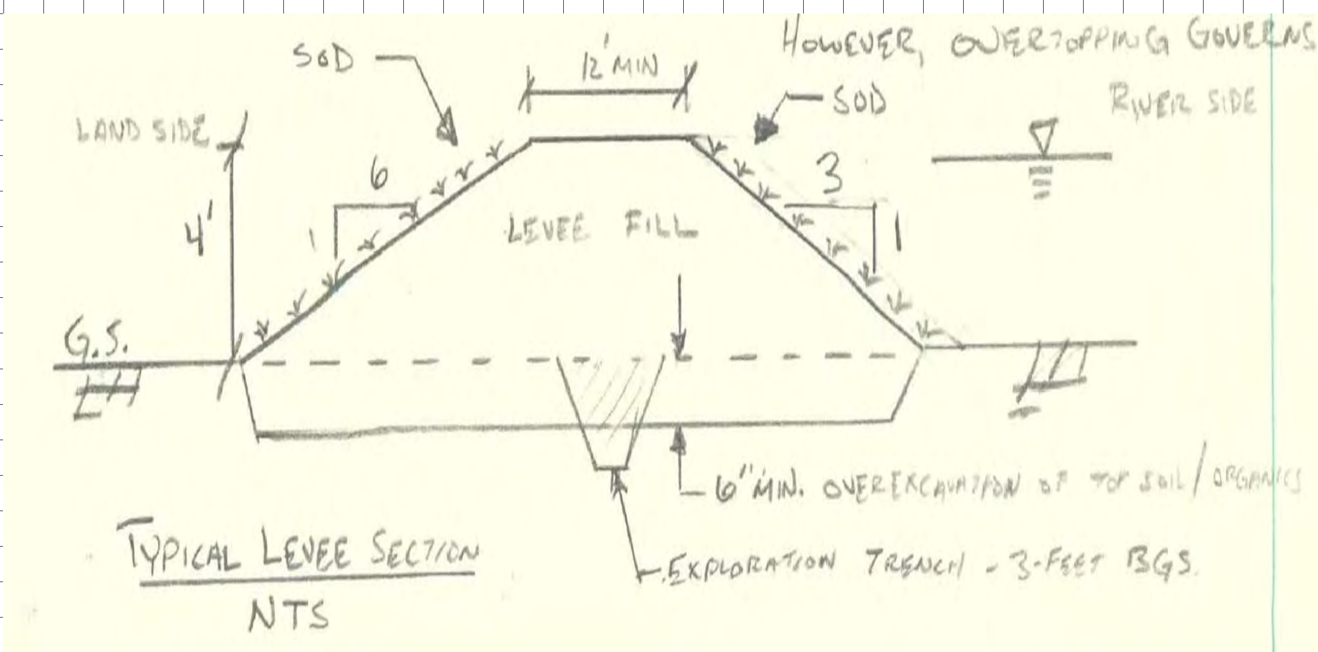
DATE AND TIME PLOTTED: $$$DATE$$$$

U.S. ARMY CORPS OF ENGINEERS

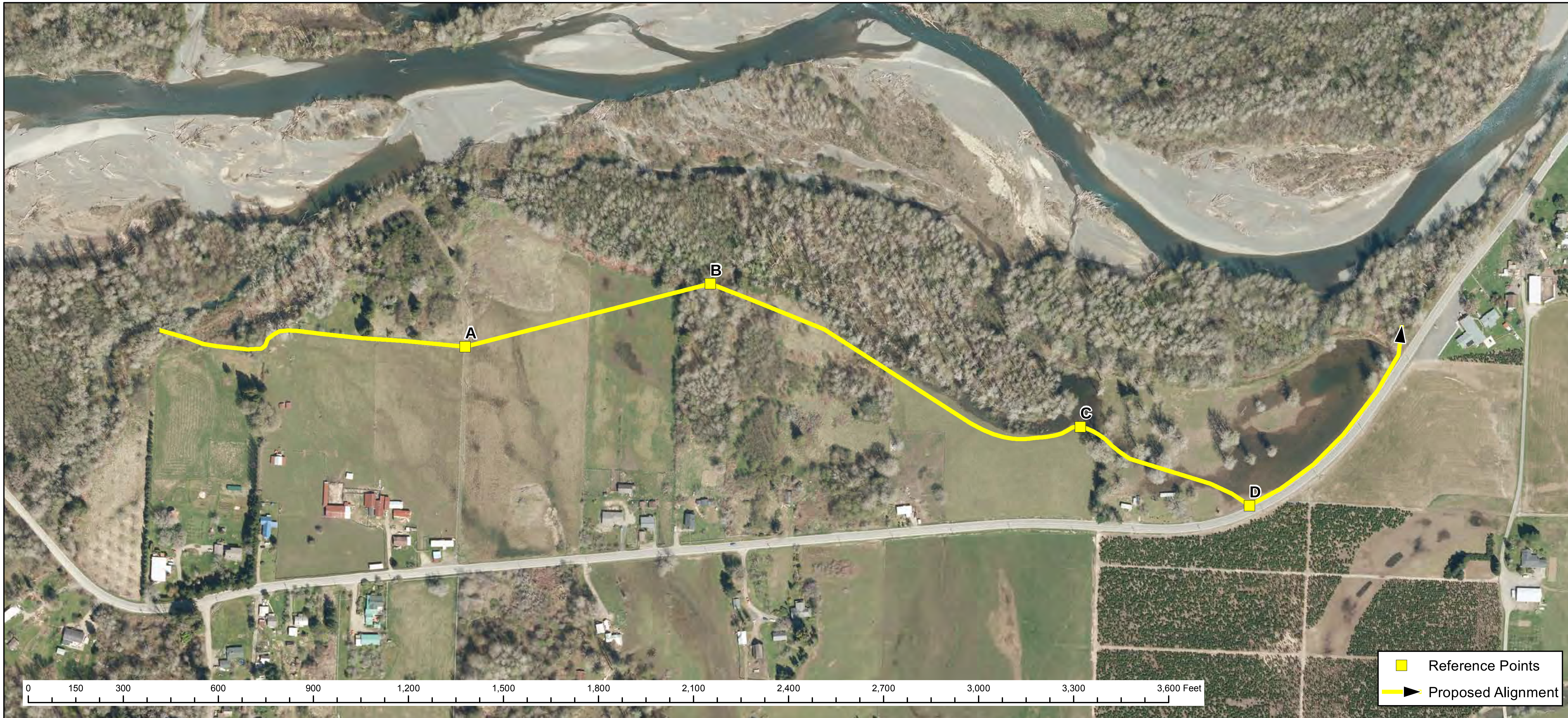
PROJECT: **Skok River Ecosystem Rest. GI**	COMPUTED BY: Rosa Radding	DATE: 15-Feb-2013
SUBJECT: **Large Levee Proposed Setback**	CHECKED BY:	SHT. 1 of 1

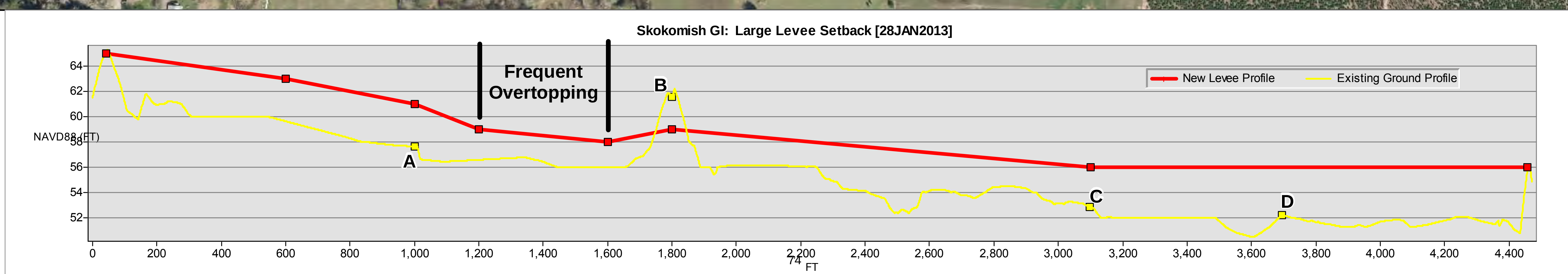
Proposed Large Levee Set Back

Levee Height FT Approx. 4.0'	4		
Crown Width FT =	12		
Side Slopes: Protected Side=	6	H:1V	
Side Slopes: River Side=	3	H:1V	
Depth of Overexcavation to remove Organics FT=	1		
Alignment length Ft	3,695		
Levee Fill SF	144		
Levee Fill CY	19,707		Assume 20,000 CY
Over Excavation SF	24		
Over Excavation CY	3,284		Assume 3,300 CY

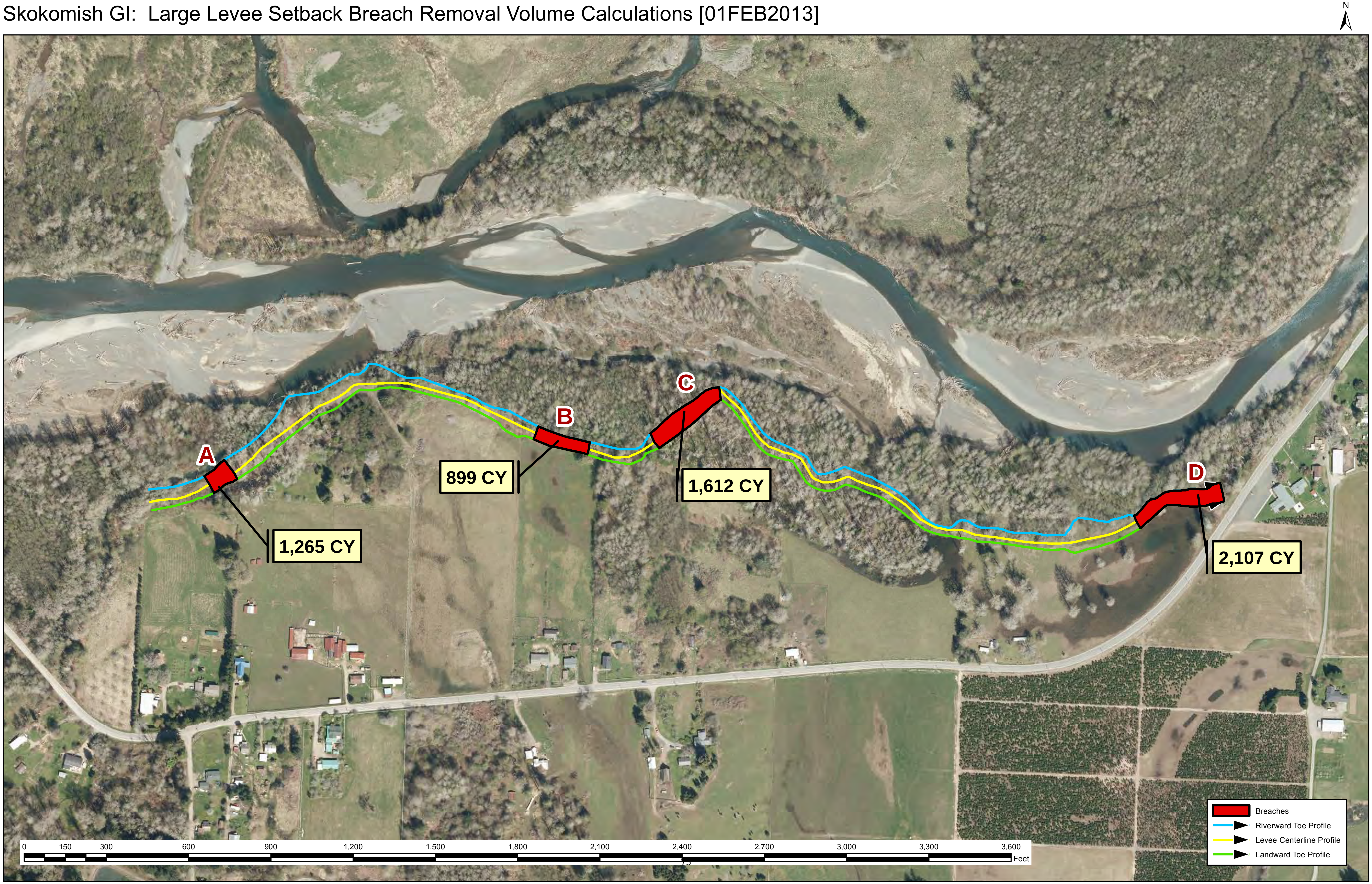


Skokomish GI: Large Levee Setback [28JAN2013]

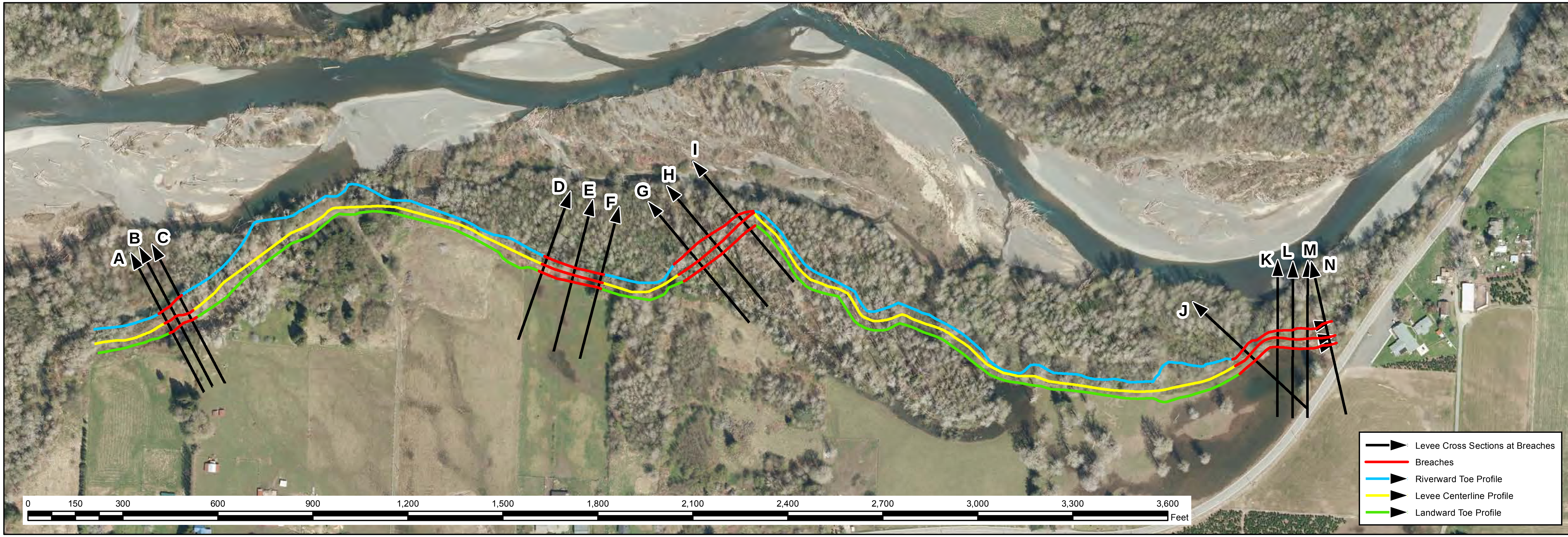


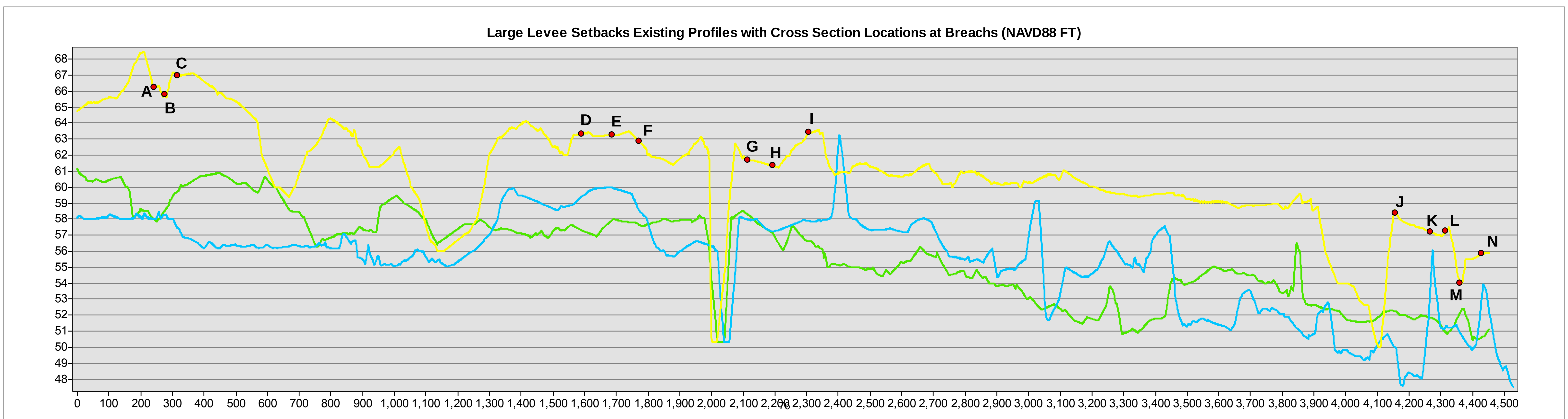


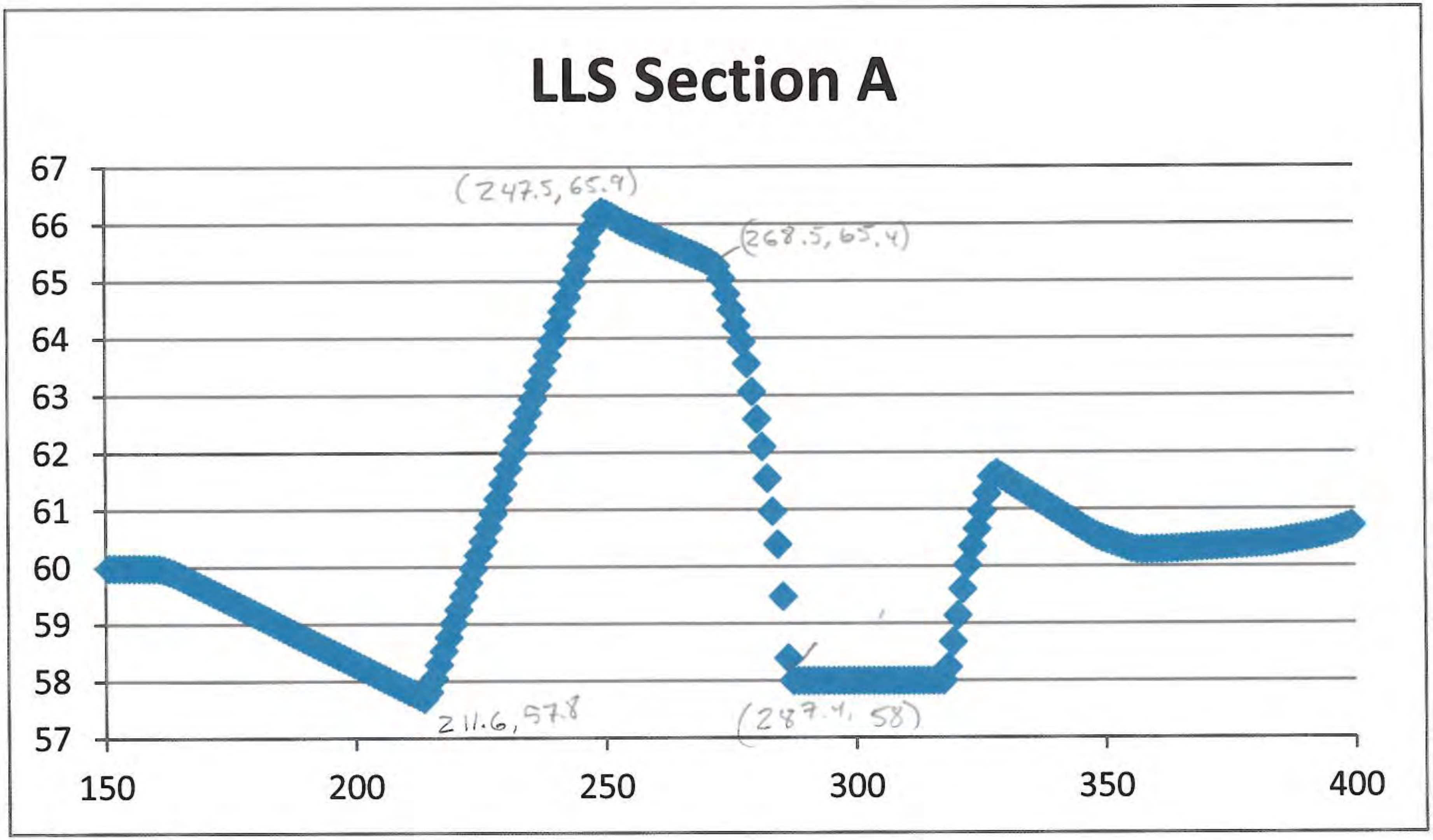
Skokomish GI: Large Levee Setback Breach Removal Volume Calculations [01FEB2013]

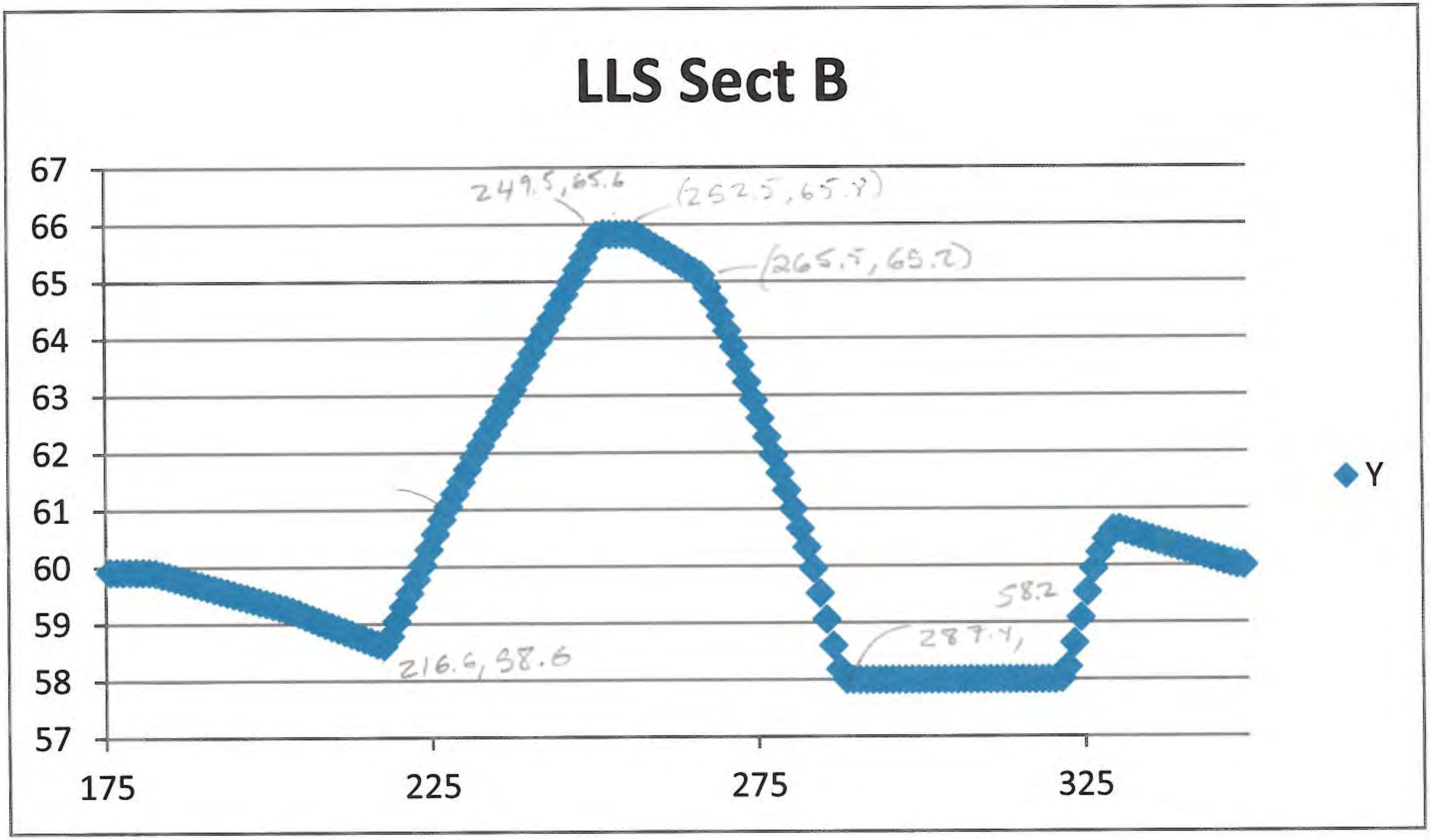


Skokomish GI: Large Levee Setback Existing Levee Profiles of Breaches [01FEB2013]

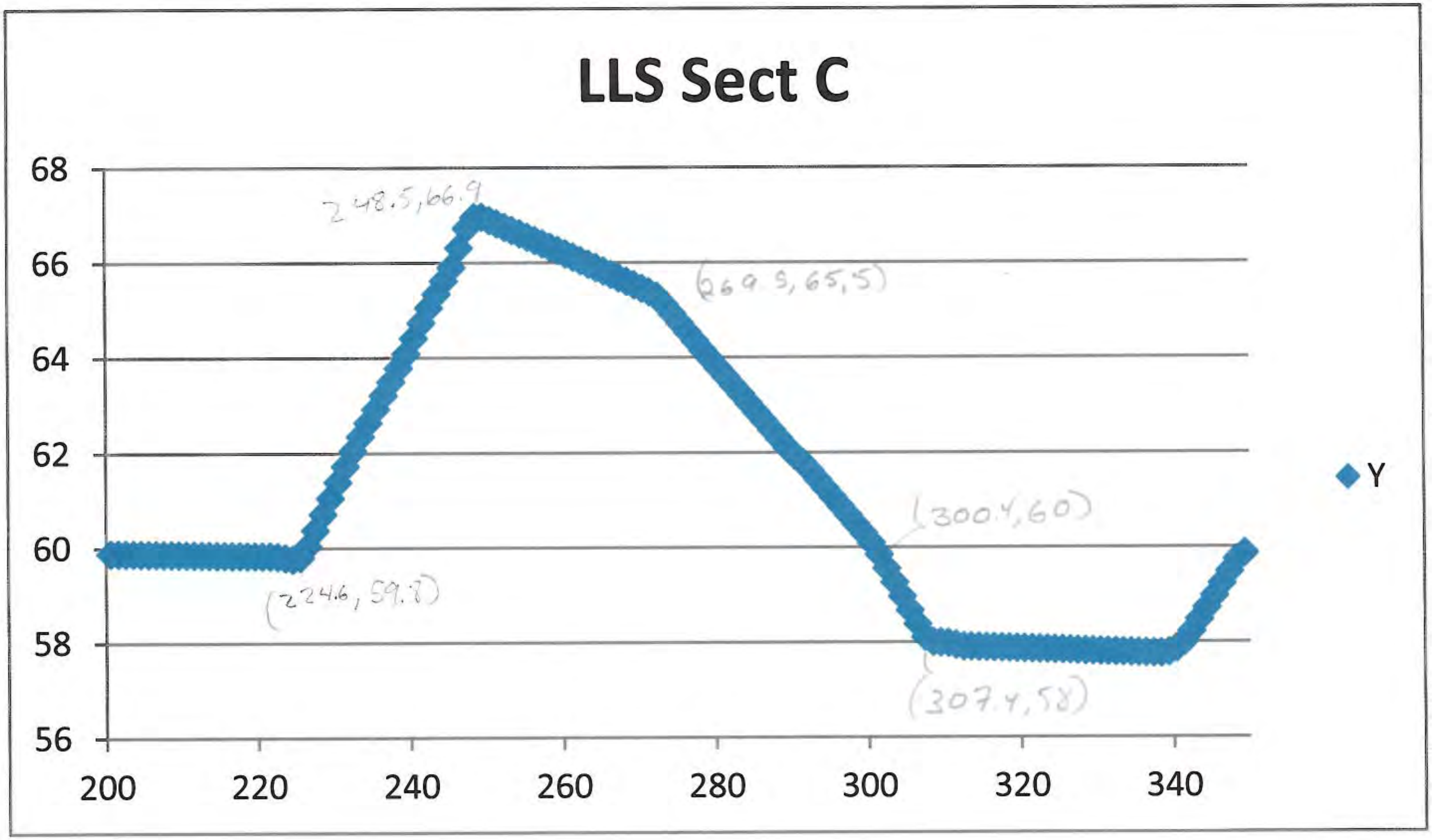


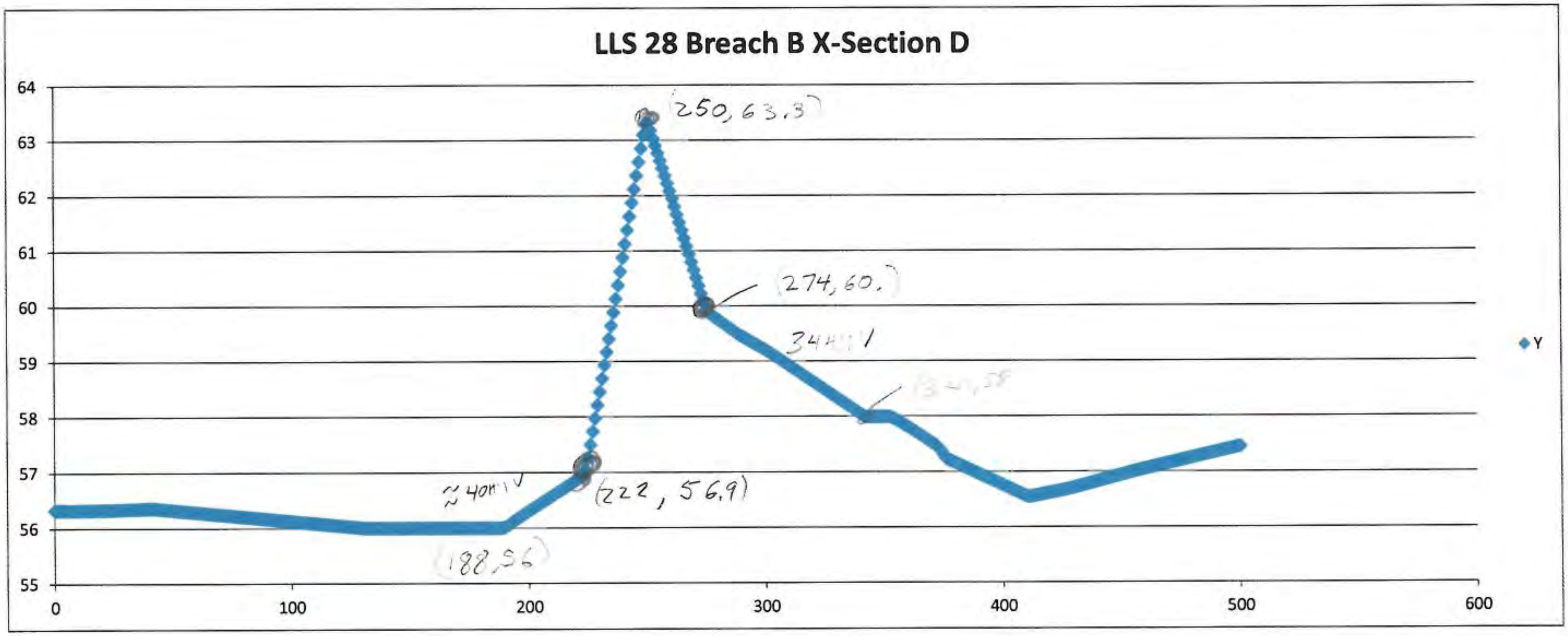



LLS Section A
67
66
65
64
63
62
61
60
59
58
57
150
200
250
300
350
400
(247.5, 65.9)
(268.5, 65.4)
211.6, 57.8
(287.4, 58)

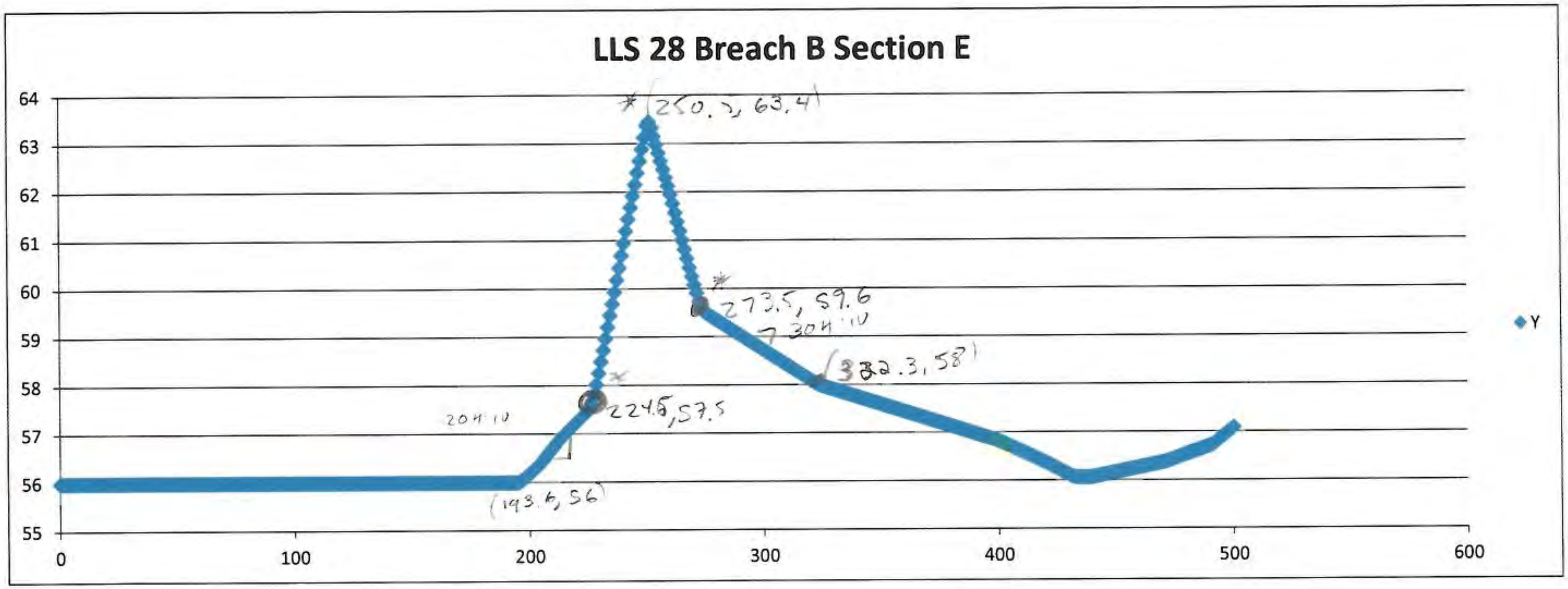


LLS Sect B
67
66
65
64
63
62
61
60
59
58
57
175
225
275
325
Y
249.5, 65.6
(252.5, 65.8)
(265.5, 65.2)
216.6, 58.6
287.4,
58.2

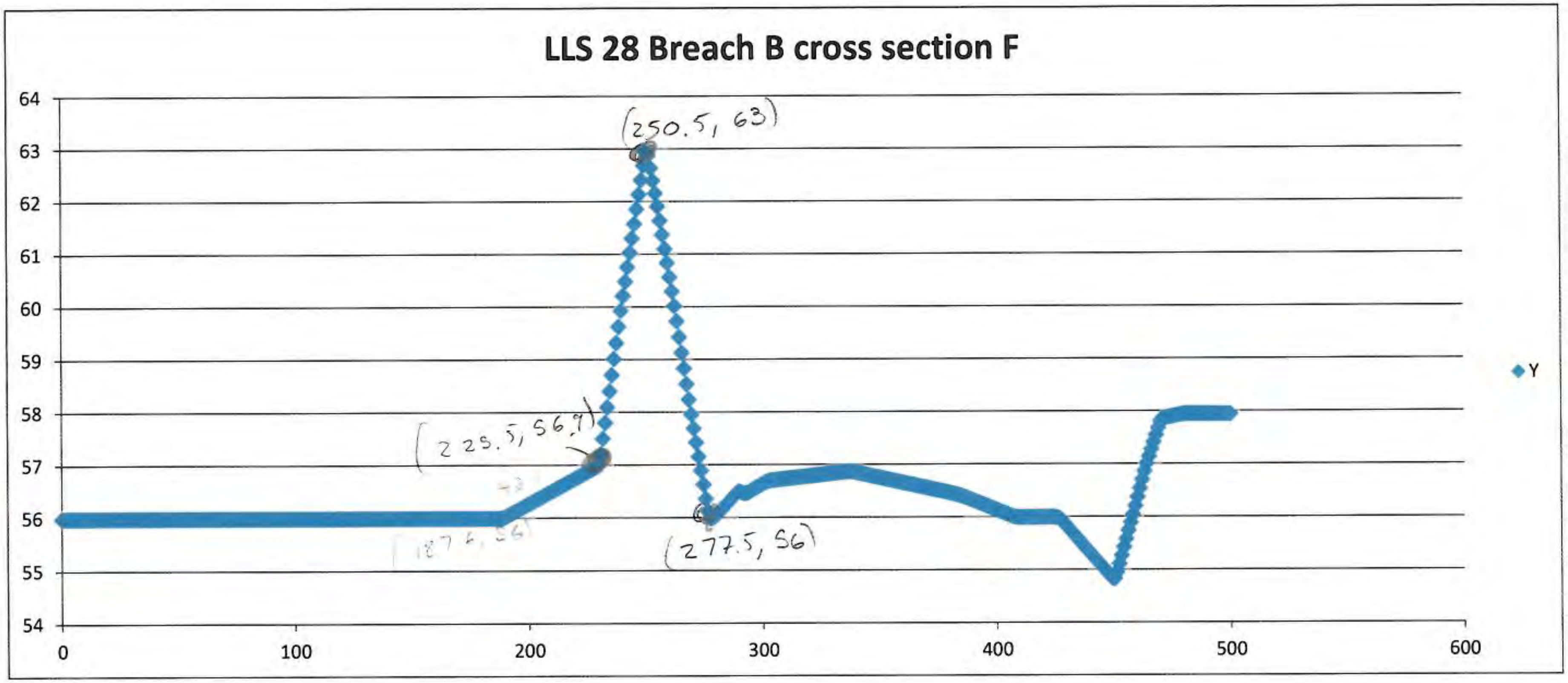

LLS Sect C
68
66
64
62
60
58
56
200
220
240
260
280
300
320
340
Y
248.5,66.9
(269.5,65.5)
(300.4,60)
(224.6,59.8)
(307.4,58)



LLS 28 Breach B X-Section D
64
63
62
61
60
59
58
57
56
55
0
100
200
300
400
500
600
Y
(250, 63.3)
(274, 60.)
(222, 56.9)
(188, 56)
≈ 40m



LLS 28 Breach B Section E
64
63
62
61
60
59
58
57
56
55
0
100
200
300
400
500
600
Y
(250.3, 63.4)
273.5, 59.6
7.30H'10
(332.3, 58)
224.5, 57.5
204'10
(193.6, 56)



LLS 28 Breach B cross section F
64
63
62
61
60
59
58
57
56
55
54
0
100
200
300
400
500
600
Y
(250.5, 63)
(225.5, 56.7)
(277.5, 56)

SKOKOMISH GI LARGE LEVEE SETBACK

Verification of GIS quantities not completed because of good agreement. Using GIS Values instead.

EXISTING LEVEE EXCAVATION CY at A= 1,312

Total Length FT Section A= 100

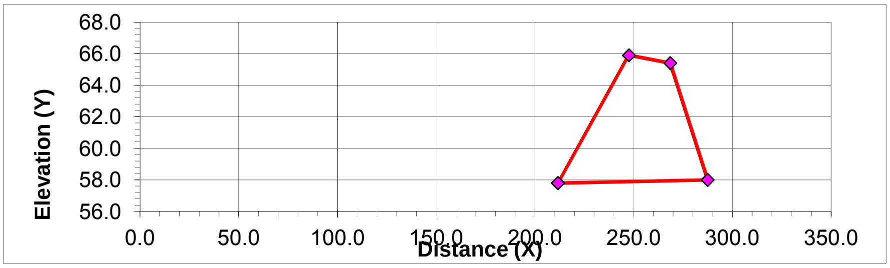
Volume CY Calculated GIS =	1265
Percent Difference from GIS=	-4%

Run A1 :	33.30		
Station :	Section A		
X	**Y**	**X1*Y2**	**Y1*X2**
212	58	13944.44	14305.5
248	66	16186.5	17694.15
269	65	15573	18795.96
287	58	16611.72	12272.8
212	58	0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		62315.66	63068.41

End Area =	376.38
Volume CY=	464

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.

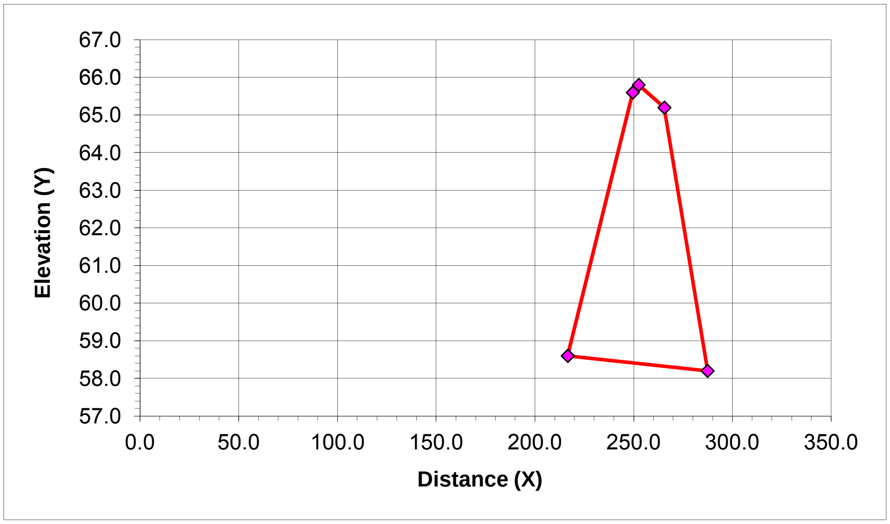


Run A2 :	33.3		
Station :	Section B		
X	**Y**	**X1*Y2**	**Y1*X2**
216.6	58.6	14208.96	14620.7
249.5	65.6	16417.1	16564
252.5	65.8	16463	17469.9
265.5	65.2	15452.1	18738.48
287.4	58.2	16841.64	12606.12
216.6	58.6	0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		0	0
		79382.8	79999.2

End Area =	308
Volume CY=	380

* Remember to reenter the 1st X1/Y1 as the last entry.

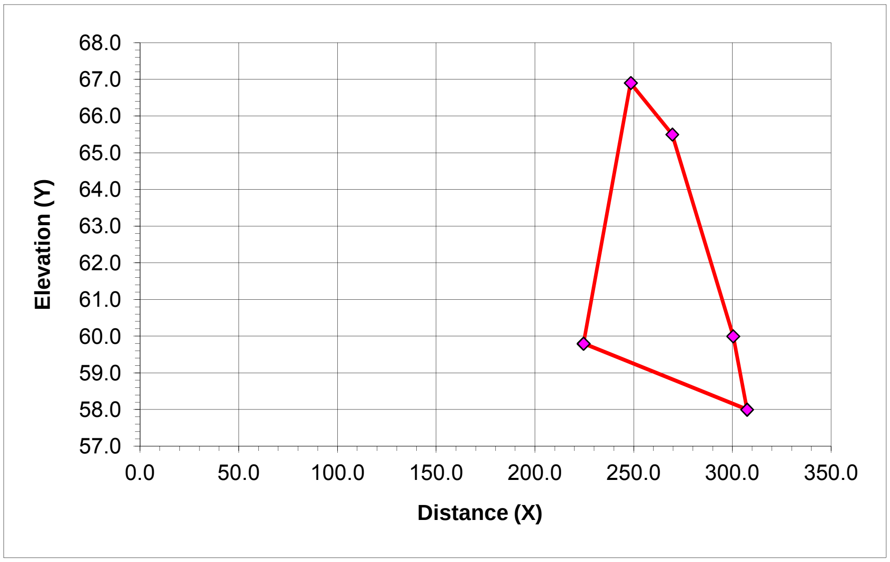
* If you have more than 16 X/Y entries just add some rows above Row 20.



Run A3 :	33.3			**End Area =**	379
Station :	Section C			**Volume CY=**	468
X	**Y**	**X1*Y2**	**Y1*X2**		
224.6	59.8	15025.74	14860.3		
248.5	67	16276.75	18029.55		
269.5	66	16170	19676.2		
300.4	60	17423.2	18444		
307.4	58	18382.52	13026.8		
224.6	59.8	0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		83278.21	84036.85		

* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.



Total Length FT Section B= 200

EXISTING LEVEE EXCAVATION CY at B= 803

Run B1 :	67			**End Area =**	36.6
Station :	Section D			**Volume CY=**	91
X	**Y**	**X1*Y2**	**Y1*X2**		
222	56.9	14052.6	14225		
250	63.3	15000	15635.1		
247	60	14054.3	13320		
222	56.9	0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		43106.9	43180.1		

Volume CY Calculated GIS =	899
Percent Difference from GIS=	11%

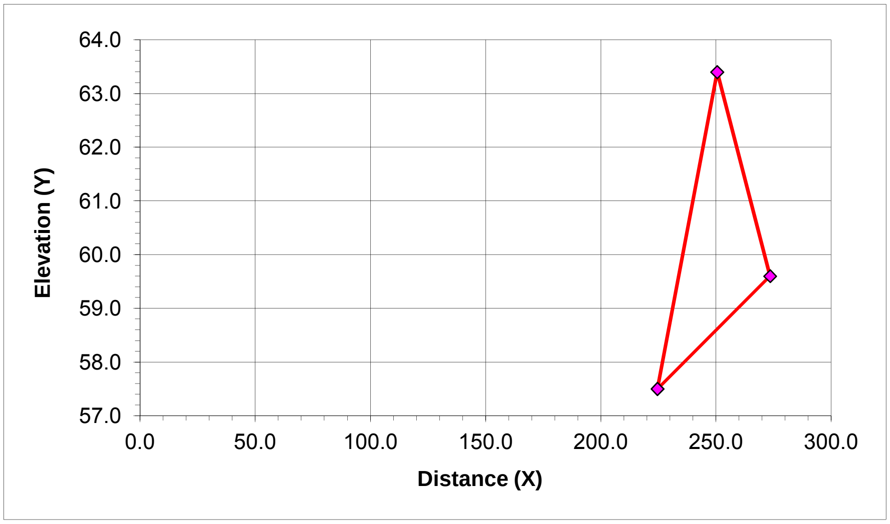
* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.

Run B2 :	67.00			End Area =	117.06
Station : E					290.5
X	Y	X1*Y2	Y1*X2		
224.6	57.5	14239.64	14403.75		
251	63	14929.8	17339.9		
274	60	15726.25	13386.16		
224.6	57.5	0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		44895.69	45129.81		

* Remember to reenter the 1st X1/Y1 as the last entry.

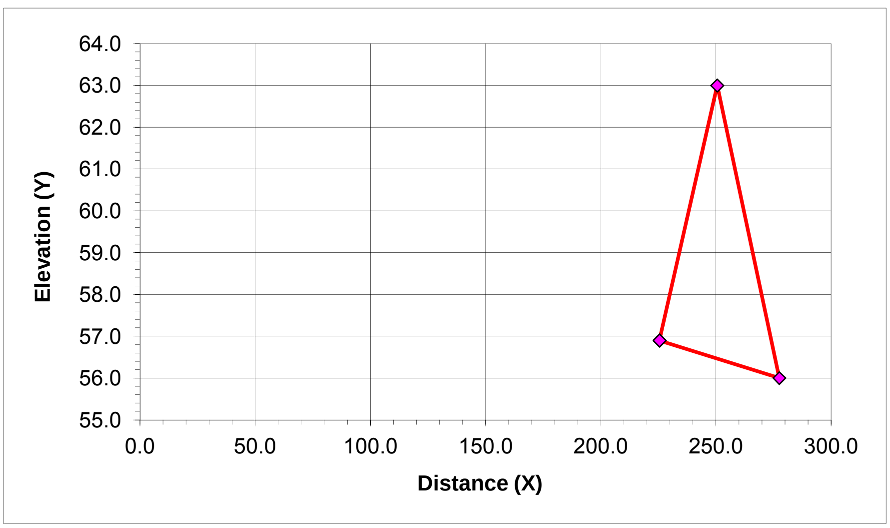
* If you have more than 16 X/Y entries just add some rows above Row 20.



Run B3 :	67.00			End Area =	169.85
Station : F					421.5
X	Y	X1*Y2	Y1*X2		
225.5	56.9	14206.5	14253.45		
251	63	14028	17482.5		
278	56	15789.75	12628		
225.5	56.9	0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		0	0		
		44024.25	44363.95		

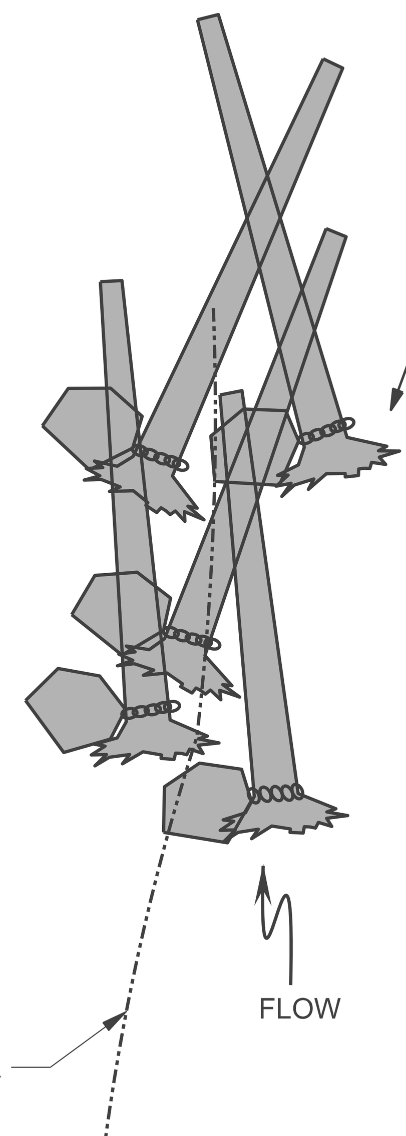
* Remember to reenter the 1st X1/Y1 as the last entry.

* If you have more than 16 X/Y entries just add some rows above Row 20.

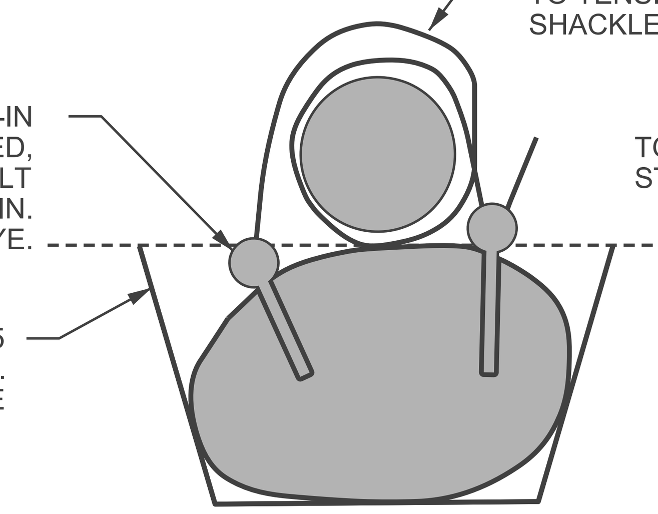


Large Woody Debris

Proposed Structures



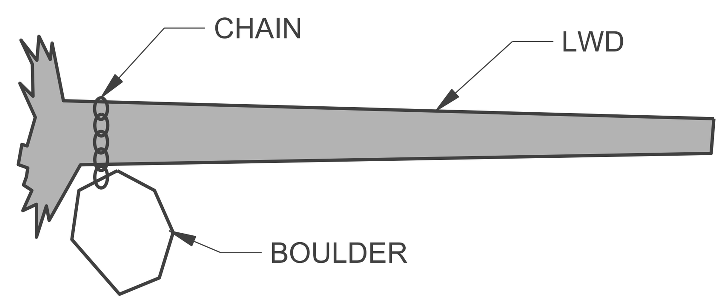
LWD CLUSTER AND INDIVIDUAL PIECE PLACEMENT
NOT TO SCALE



TYPICAL LOG TO BOULDER ANCHOR CONNECTION
NOT TO SCALE

BOULDER-LOG CHAIN CONNECTION SCHEDULE:

LOG DIAMETER (FT)	CHAIN LENGTH (FT)
3	21
4	27



SINGLE ANCHORED LOG
NOT TO SCALE

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PLOT TIME: 2:16:39 PM
SIZE: ANSI D

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832

LARGE WOODY DEBRIS
DETAILS

SHEET IDENTIFICATION
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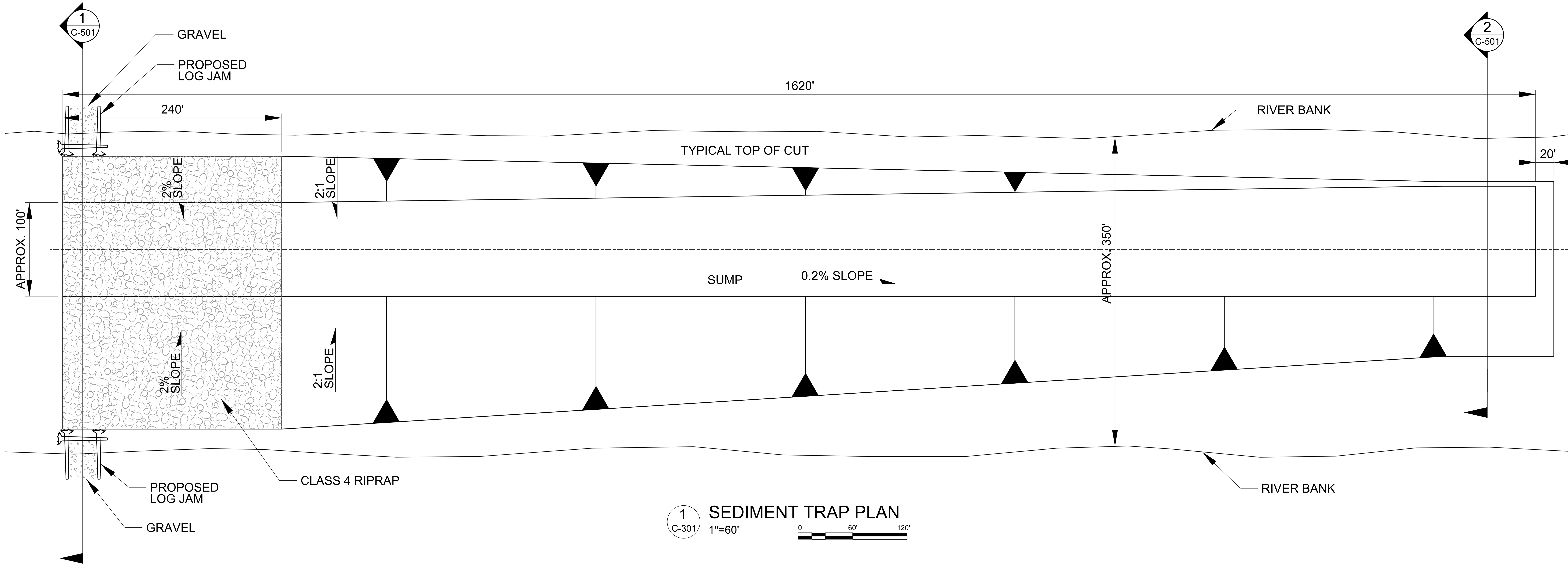
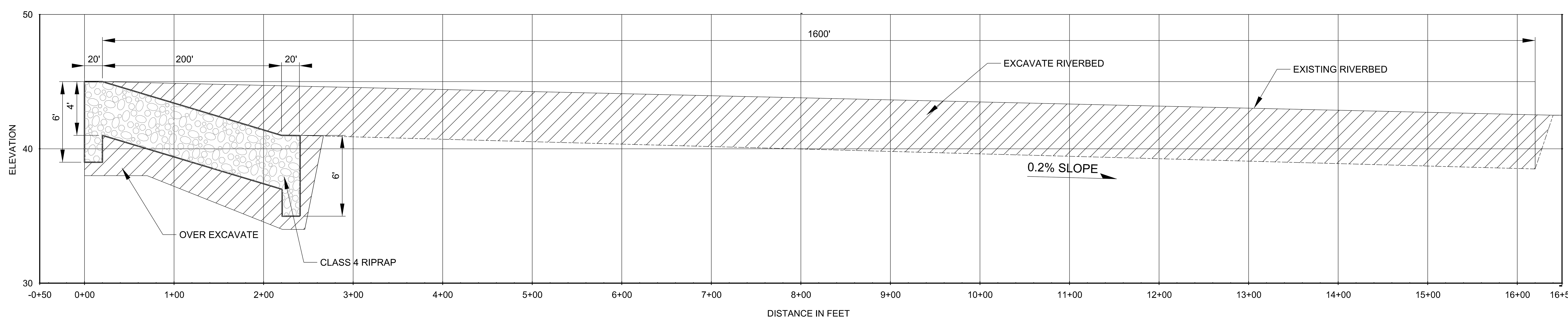
DATE AND TIME PLOTTED: 10/23/2013

Sediment Trap Calculations



1 C-301 **SEDIMENT TRAP PLAN**
1"=60'



1 C-301 **SEDIMENT TRAP PROFILE**
HORZ 1"=60'
VERT 1"=4'
VERT. EXAGGERATION x 15

SEDIMENT REMOVAL TYPICAL SECTIONS FOR ALTERNATIVES 1 & 5

ALTERNATIVE 1 RM 0 - 9.0
ALTERNATIVE 5 RM 3.5 - 9.0

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SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
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SEDIMENT TRAP
PLAN AND PROFILE

SHEET IDENTIFICATION
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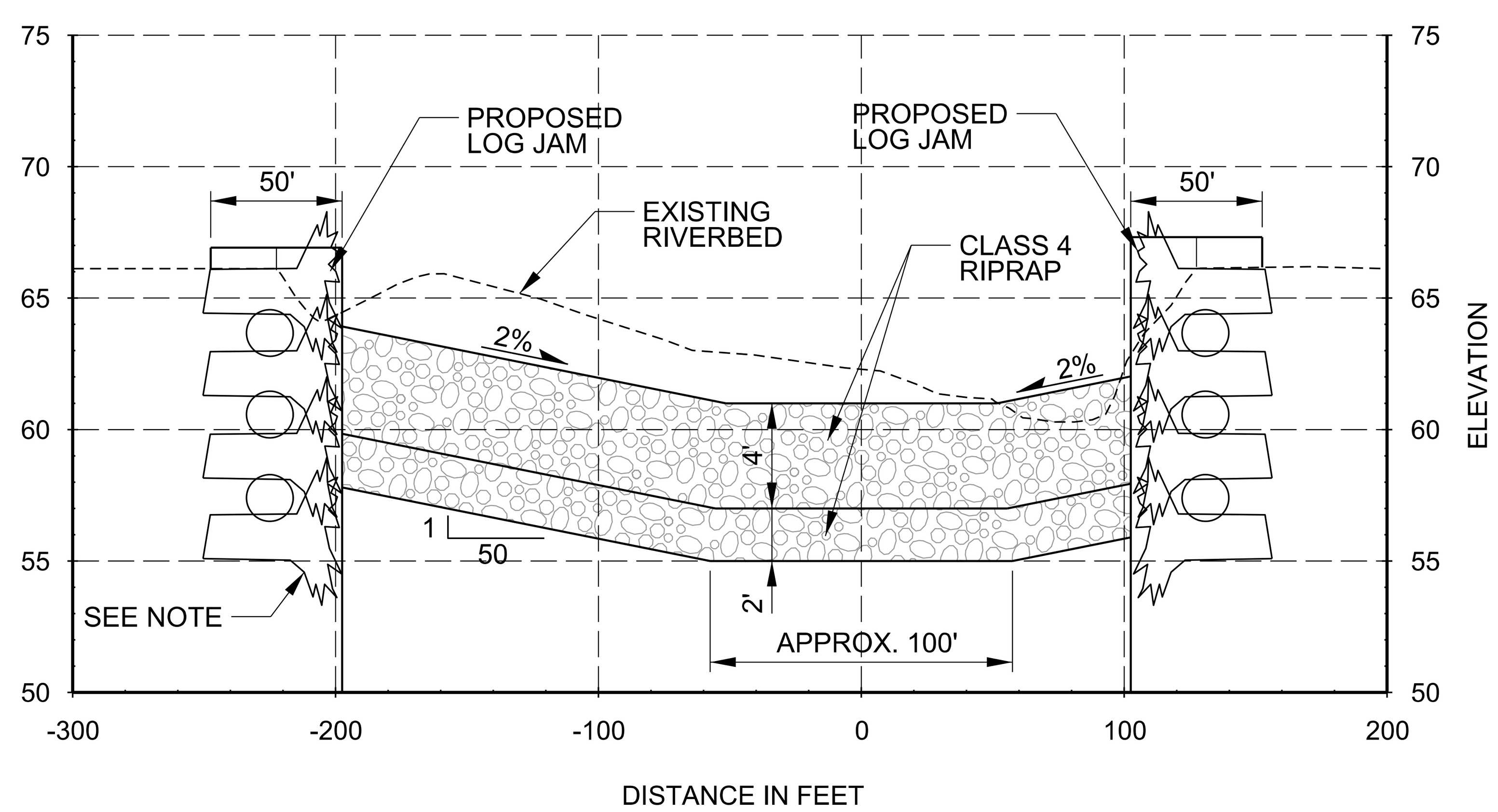
DESIGN FILE: c:\users\g3ecdlal\documents\cenws01\dms73333\PN60344_SKOK-C-SED_TRPLNAlt111.DGN

DATE AND TIME PLOTTED: $$$DATE$$$$

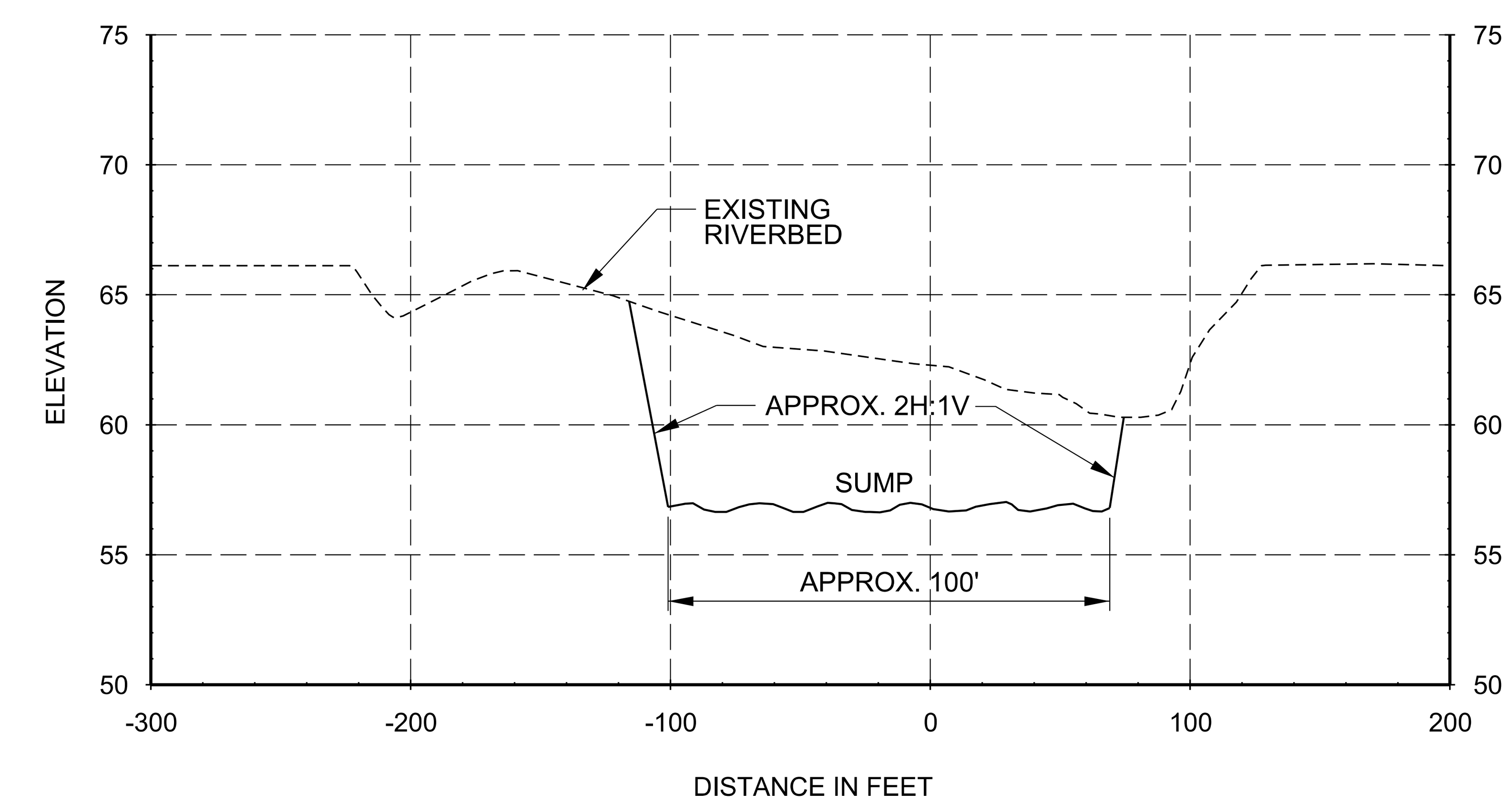


1 TYPICAL WEIR CREST CROSS SECTION

C-301

HORZ 1"=60'
VERT 1"=6'

VERT. EXAGGERATION x 10



2 TYPICAL SUMP CROSS SECTION

C-301

HORZ 1"=60'
VERT 1"=6'

VERT. EXAGGERATION x 10

NOTE:

1. TWENTY-TWO (22) - ≈18" DIA. LOGS WITH ROOT WAD

EARTHWORK (CY)			
RIVERBED EXCAVATION	OVEREXCAVATION		BACKFILL IN LOG JAM
	ROCK WEIR	LOG JAM	
41,800	15,500	1,150	1,150

WEIR CLASS 4 RIPRAP (CY)
9,550

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CKD BY:
SUBMITTED BY:
PLOT DATE: 2/12/2013
PLOT TIME: 11:18:13 AM
SIZE: ANSI D
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DATE: DD MONTH 2011
SOLICITATION NO.: XXXXXX-00-X-0002
CONTRACT NO.: XXXXXX-00-X-0000
FILE NUMBER: E-25-1-22

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832
SEDIMENT TRAP CROSS SECTIONS

SHEET IDENTIFICATION
C-301
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DESIGN FILE: c:\users\g3ecdrd9\documents\cenws01\dms73333\PN60344_SKOK-C-SED TRP CROSS-SECTIONS.DGN

DATE AND TIME PLOTTED: $$$DATE$$$$

U.S. ARMY CORPS OF ENGINEERS

PROJECT: **Skok River Ecosystem Rest. GI**	COMPUTED BY: Michael Peele	DATE: 11-Feb-2013
SUBJECT: **Sediment Trap Calcs**	CHECKED BY: Rosa Radding	SHT. 1 of 2

River bed Excavation

Length=	1620	ft
Width=	100	ft
Left side width=	8	ft
Right side width=	140	ft
Average Depth=	4	ft

Assumptions:
- 4' average depth of excavation
- Left Slope width to be 8'
- Right Slope witdth to be 140'
- 1' of overexcavation under riprap

Excavation= LxWxD+RWxDx1/2xL+LWxDX1/2xL

	1,127,520.00	cu ft
Excavation=	41,760	cu yd

Weir Over Excavation

Length=	240	ft
Width=	100	ft
Left side width=	8	ft
Right side width=	140	ft
Average Depth=	7	ft

Excavation= LxWxD+RWxDxL+LWxDxL

	416,640.00	cu ft
Excavation=	15,431	cu yd

Riprap for Weir

Length=	240	ft
Width=	100	ft
Left side width=	8	ft
Right side width=	140	ft
Average Depth=	4	ft

Keys (2)

Length=	20	ft
Width=	248	ft
Depth=	2	ft

Class IV Riprap= LxWxD+RWxDxL+LWxDxL+2*L(K)*W(K)*D(K)

	257,920.00	cu ft
Riprap=	9,553	cu yd

U.S. ARMY CORPS OF ENGINEERS

PROJECT:	**Skok River Ecosystem Rest. GI**	COMPUTED BY: Michael Peele	DATE: 11-Feb-2013
SUBJECT:	**Sediment Trap Calcs**	CHECKED BY: Rosa Radding	SHT. 2 of 2

Assumptions:
- Log Jams to be 4 logs deep
- Excavation for log jams to be 50'x50'x12'

Excavation= 50'x50'x12'

	30000	cu ft
Excavation=	1111	cu yd

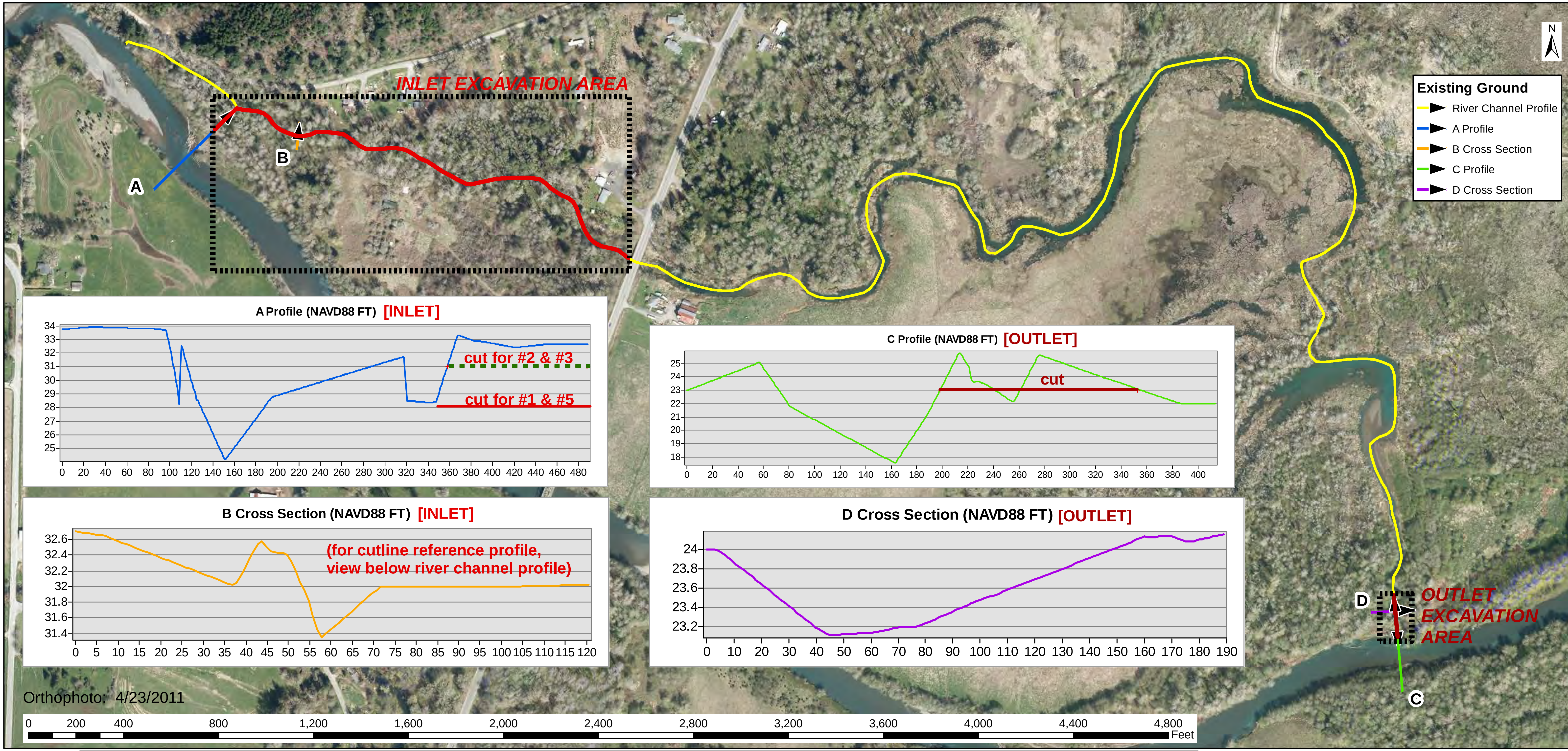
Log Jams (2)
- 4 logs on 2 sides
- 3 logs on face

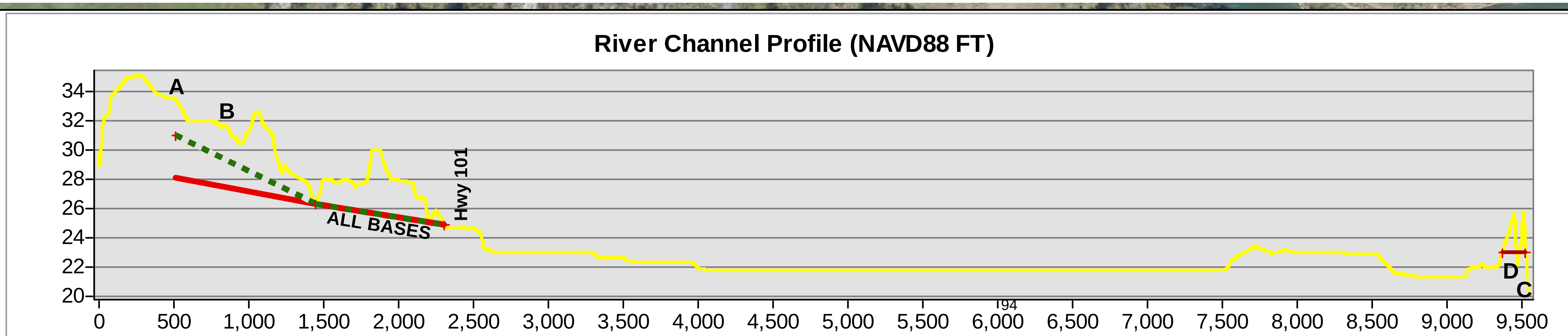
Total of 22 logs

Side Channel #9 Calculations

Side Channel Excavations

Skokomish GI: River Channel #9 Profiles and Cross Sections (NAVD88 FT) [25FEB2013]





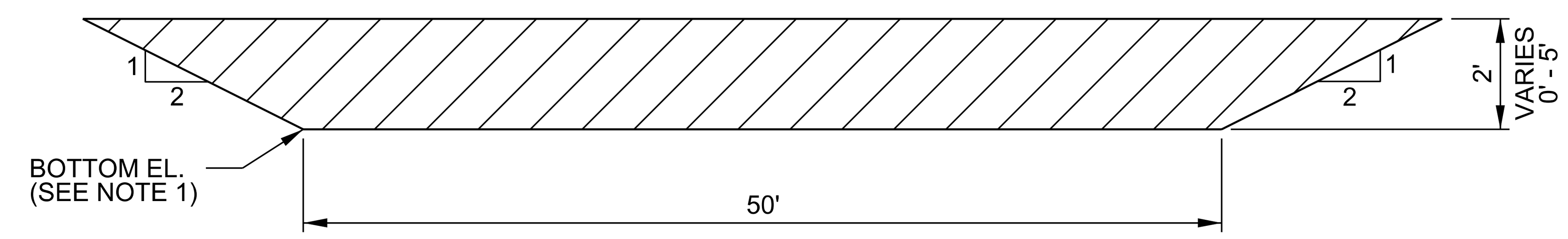
INLET CUTLINE

Proposed cut used in conjunction with Base #1 & #5

Proposed cutline used in conjunction with Base #2 & #3

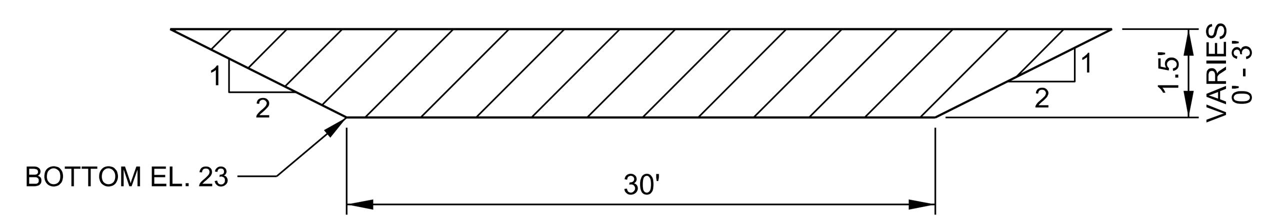
OUTLET CUTLINE

[SEE TYPICALS FOR SECTIONS]



SEE NOTES 1 AND 2

TYPICAL INLET CHANNEL CUT CROSS SECTION A AND B



TYPICAL OUTLET CHANNEL CUT CROSS SECTION C

BOTTOM EL. OF CUT (FT)	APPROX. VOLUME OF CUT (CY) (SEE NOTE 1)		
	A	B	C
28	1,400	14,270	300

BOTTOM EL. OF CUT (FT)	APPROX. VOLUME OF CUT (CY) (SEE NOTE 2)		
	A	B	C
31	400	7,750	300

INCREMENT RIVER CHANNEL RECONNECTION RM 4 -5.6(#9)

NOT TO SCALE

NOTES:

1. INCREMENT EXECUTED IN CONJUNCTION WITH BASE ALTERNATIVES 1 AND 5.
2. INCREMENT EXECUTED IN CONJUNCTION WITH BASE ALTERNATIVES 2 AND 3.

US Army Corps of Engineers®
SEATTLE DISTRICT

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832

RIVER CHANNEL CUT (#9)

SHEET IDENTIFICATION
C-301

U.S. ARMY CORPS OF ENGINEERS

PROJECT: Skok River Ecosystem Rest. GI	COMPUTED BY: Rosa Radding	DATE: 13-Feb-2013
SUBJECT: Increment #9 Inlet w/ Bases 1 & 5	CHECKED BY:	SHT. 1 of 2

<u>Inlet Along Alignment A Executed in Conjunction with Base Alternatives 1&5</u>

Length=	142	ft	
Width=	50	ft	
Side Slope Width=	9	ft	
Right side width=	9	ft	
Average Depth=	4.5	ft	

Assumptions:
- 4.5' average depth of excavation
- 2H:1V Side Slopes
- Bottom Elevation 28
- Station 488.5- Station 346.6 Profile A

Excavation= LxWxD+RWxDx1/2xL+LWxDX1/2xL

	37,674.45	cu ft
Excavation=	1,395	cu yd

<u>Inlet Along Alignment B1</u>

Length=	971	ft
Width=	50	ft
Left side width=	10	ft
Right side width=	10	ft
Average Depth=	5	ft

Assumptions:
- 4.5' average depth of excavation
- 2H:1V Side Slopes
- Bottom Elevation Varies from El 28 to El 26
- Station 1431- Station 460 Profile B

Excavation= LxWxD+RWxDxL+LWxDxL

	291,300.00	cu ft
Excavation=	10,789	cu yd

<u>Inlet Along Alignment B2</u>

Length=	869	ft
Width=	50	ft
Left side width=	4	ft
Right side width=	4	ft
Average Depth=	2	ft

Assumptions:
- 2' average depth of excavation
- 2H:1V Side Slopes
- Bottom Elevation Varies from El 25 to El 26
- Station 2300- Station 1431 Profile B

Excavation= LxWxD+RWxDxL+LWxDxL

	93,852	cu ft
Excavation=	3,476	cu yd
Sum Inlet B=	14,265	cu yd
Sum Inlet AB	15,660	cu yd

U.S. ARMY CORPS OF ENGINEERS

PROJECT: **Skok River Ecosystem Rest. GI**		COMPUTED BY: Michael Peele	DATE: 11-Feb-2013
SUBJECT: **Increment #9 Outlet w/ Bases 1 & 5**		CHECKED BY: Rosa Radding	SHT. 2 of 2

Outlet Along Alignment B2

Length=	160	ft
Width=	30	ft
Left side width=	3	ft
Right side width=	3	ft
Average Depth=	1.5	ft

Excavation= LxWxD+RWxDxL+LWxDxL

	7,920	cu ft
Excavation=	293	cu yd

Assumptions:

2' average depth of excavation
2H:1V Side Slopes
Bottom Elevation 23
Station 9361- Station 9526 Profile B

PROJECT: **Skok River Ecosystem Rest. GI**	COMPUTED BY: Rosa Radding	DATE: 13-Feb-2013
SUBJECT: **Increment #9 Inlet w/ Bases 2 & 3**	CHECKED BY:	SHT. 1 of 2

Inlet Along Alignment A Executed in Conjunction with Base Alternatives 2&3

Length=	131	ft	
Width=	50	ft	
Side Slope Width=	3	ft	
Right side width=	3	ft	
Average Depth=	1.5	ft	

Assumptions:
- 1.5' average depth of excavation
- 2H:1V Side Slopes
- Bottom Elevation 31
- Station 488.5- Station 357.6 Profile A

Excavation= LxWxD+RWxDx1/2xL+LWxDX1/2xL

	10,406.55	cu ft
Excavation=	385	cu yd

Inlet Along Alignment B

Length=	1840	ft
Width=	50	ft
Left side width=	4	ft
Right side width=	4	ft
Average Depth=	2	ft

Assumptions:
- 2' average depth of excavation
- 2H:1V Side Slopes
- Bottom Elevation Varies from El 25 to El 31
- Station 2300- Station 460 Profile B

Excavation= LxWxD+RWxDxL+LWxDxL

	198,720	cu ft
Excavation=	7,360	cu yd
Sum Inlet=	7,745	cu yd

U.S. ARMY CORPS OF ENGINEERS

PROJECT:	**Skok River Ecosystem Rest. GI**	COMPUTED BY: Michael Peele	DATE: 11-Feb-2013
SUBJECT:	**Increment #9 Outlet w/ Bases 2 & 3**	CHECKED BY: Rosa Radding	SHT. 2 of 2

Outlet Along Alignment B2

Length=	160	ft
Width=	30	ft
Left side width=	3	ft
Right side width=	3	ft
Average Depth=	1.5	ft

Excavation= LxWxD+RWxDxL+LWxDxL

	7,920	cu ft
Excavation=	293	cu yd

Assumptions:

2' average depth of excavation

2H:1V Side Slopes

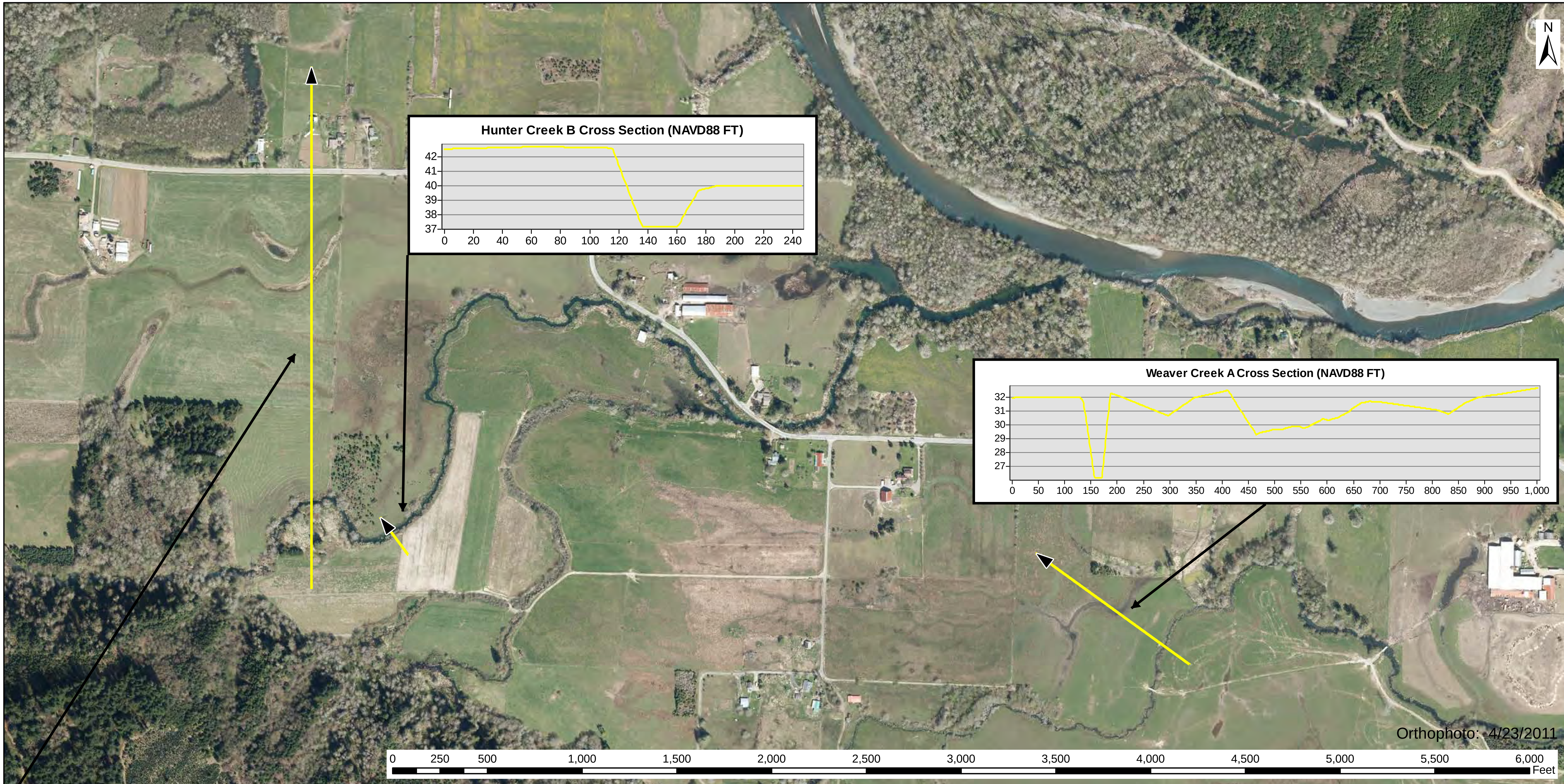
Bottom Elevation 23

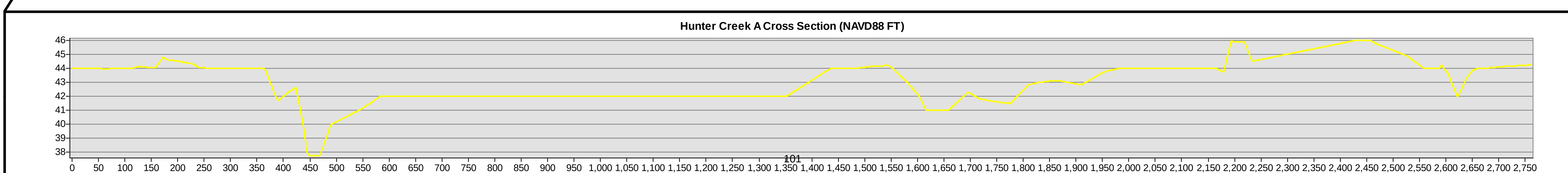
Station 9361- Station 9526 Profile B

Weaver & Hunter Creek Calculations

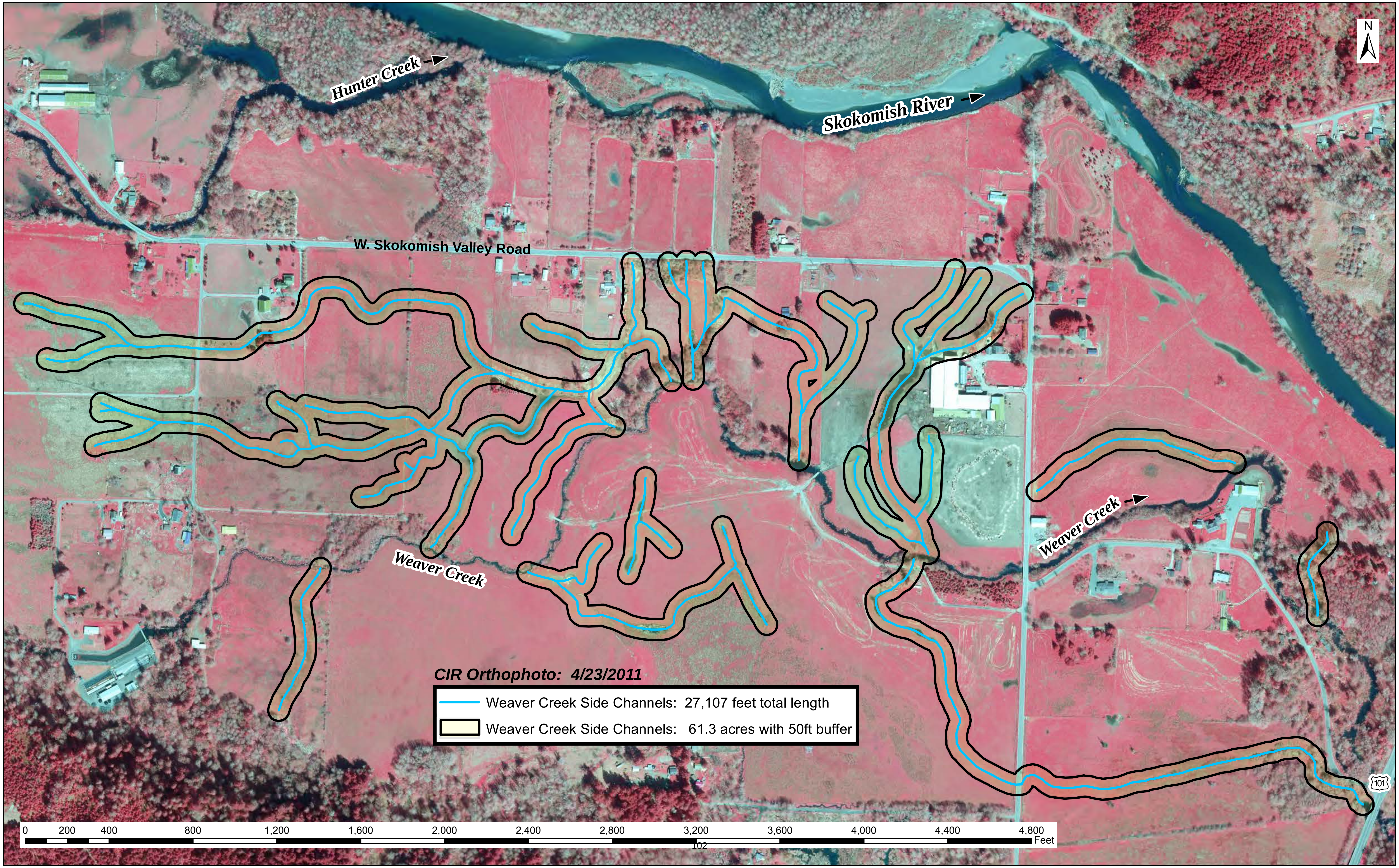
MOUTHS & SIDE CHANNEL EXCAVATIONS

Skokomish GI Potential Projects: Hunter Creek #40 and Weaver Creak #43 Profiles (NAVD88 FT) [29JAN2013]

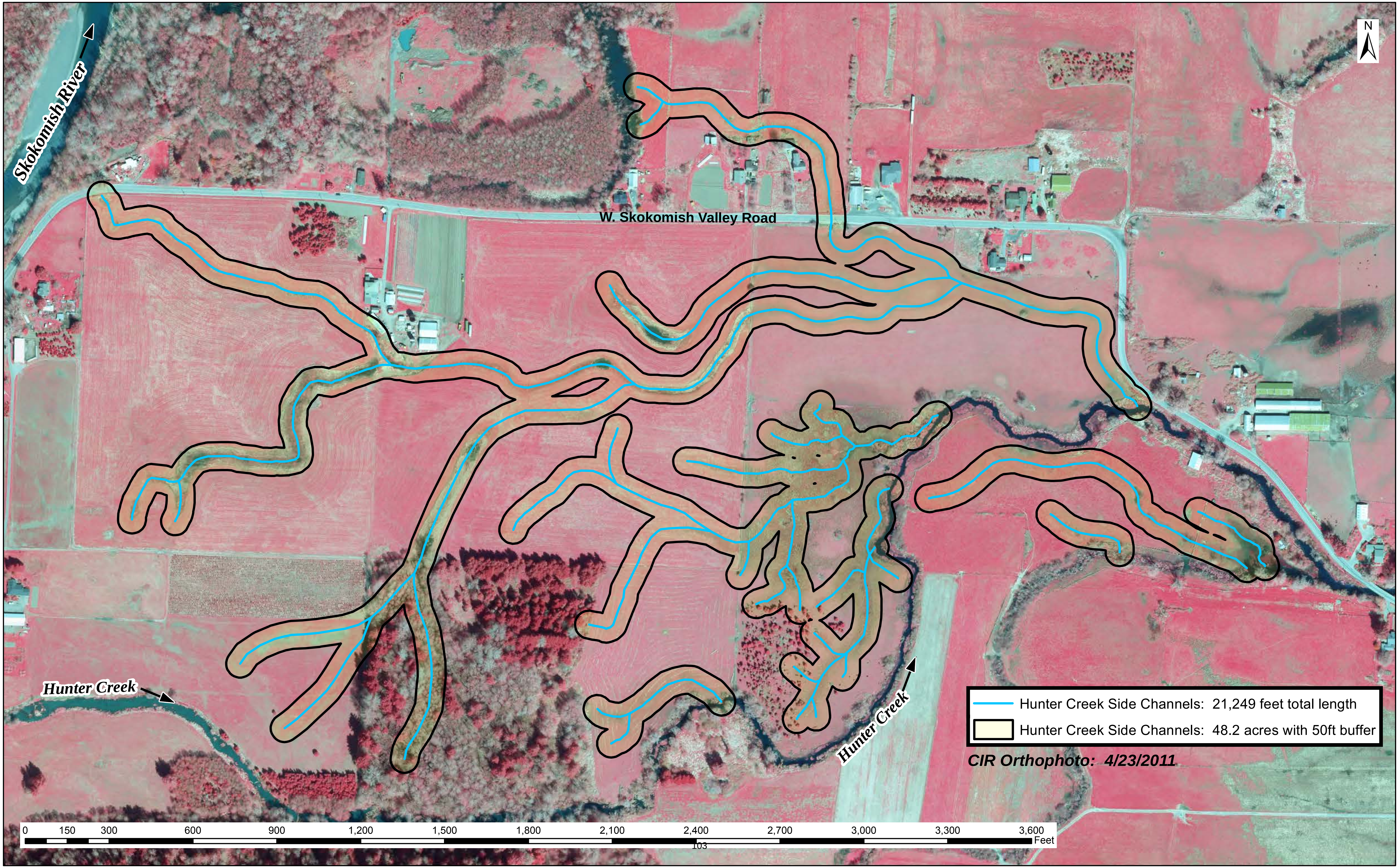


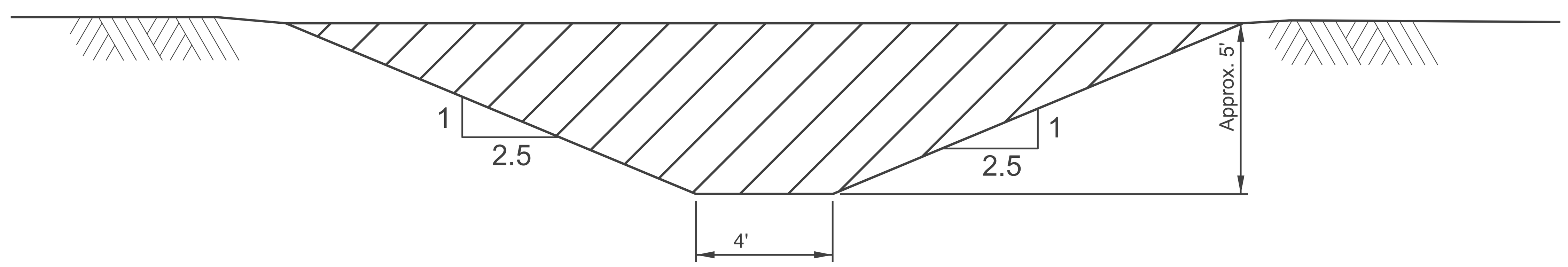


Skokomish GI: Weaver Creek Side Channels with 50ft Buffer [05FEB2013]



Skokomish GI: Hunter Creek Side Channels with 50ft Buffer [05FEB2013]





WEAVER AND HUNTER MOUTHS & SIDE CREEKS EXCAVATION

NOT TO SCALE

SIDE CREEK EXCAVATION

APPROX. VOLUME = 148,060 CY

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SEATTLE DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT
SEATTLE, WASHINGTON

DESIGNED BY: ERIKSEN
DWN BY: RB
CKD BY:
SUBMITTED BY:
DATE: DD MONTH 2011
SOLICITATION NO.: X000XX-00-X-0002
CONTRACT NO.: X000XX-000-0000
FILE NUMBER: E-25-1-22
PLOT DATE: 10/23/2013
PLOT TIME: 4:19:47 PM
SIZE: ANSI D
FILE NAME: PN60344_SKOK-C-WEAVER_HUNTER_CREEKS.DGN

SKOKOMISH RIVER ECOSYSTEM RESTORATION
GENERAL INVESTIGATION
SKOKOMISH RIVER, WASHINGTON
PN394832

HUNTER WEAVER CREEKS EXCAVATION

SHEET IDENTIFICATION
C-301
SHEET OF

DESIGN FILE: pw:\\NWS-AS01PJW.nws.ds.usace.army.mil:cenws01\Documents\Civil Works\Skokomish River, WA\FY16 PN394832 SKOK\Current Phase\Con_Docs\CAD_Sh

DATE AND TIME PLOTTED: 10/23/2013

U.S. ARMY CORPS OF ENGINEERS

PROJECT: **Skok River Ecosystem Rest. GI**	COMPUTED BY: Rosie Brouse	DATE: 22-Oct-2013	
SUBJECT: **Proposed Side Channel Excavations**	CHECKED BY:	SHT. 1 of 1	

Proposed Hunter and Weaver Mouths & Side Channel Excavations

Channel Depth FT	5
Bottom Channel Width FT =	4
Side Slopes=	2.5 H:1V
Hunter Mouth length FT=	50
Hunter Alignment length FT=	21,249
Hunter Creek Channel Area SF=	82.5
Hunter Creek Channel Ex Volume CY=	65,080
Weaver Mouth length FT=	50
Weaver Alignment length FT=	27,107
Weaver Creek Channel Area SF=	82.5
Weaver Creek Channel Ex Volume CY=	82,980
Total Excavation CY=	148,060

Where Volume = Cross Sectional Area X (Length of Mouth + Length of Side Channels)

SKOKOMISH RIVER BASIN
MASON COUNTY, WASHINGTON
ECOSYSTEM RESTORATION

APPENDIX I

HAZARDOUS, TOXIC, AND RADIOACTIVE WASTE

DRAFT Integrated Feasibility Report and Environmental Impact Statement

US Army Corps
of Engineers®
Seattle District

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Skokomish River General Investigation

Hazardous, Toxic, and Radioactive Waste Preliminary Phase I Site Assessment

January 31, 2011

Skokomish General Investigation Feasibility Study
Hazardous, Toxic, and Radioactive Waste
Preliminary Phase I Site Assessment

Executive Summary

The Skokomish River, located in Mason County, Washington is the primary drainage basin for the southeast region of the Olympic Peninsula. The river flows from its headwaters in the Olympic Mountains to the Hood Canal. The basin consists of 80 mainstream river miles and 260 miles of tributaries. The Skokomish River has a long history of flooding. Sedimentation, caused by logging, has reduced the riverbed channel capacity and parts of the valley are flooded multiple times a year with the entire valley floor commonly inundated at least once a year. Pursuant to Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969, as amended, the U.S. Army Corps of Engineers is preparing an Integrated Feasibility Report/Environmental Impact Statement (FR/EIS) for proposed ecosystem restoration and flood risk management in the Skokomish River Basin. The Skokomish Indian Tribe and Mason County are the non-Federal sponsors for the project. The Preliminary Phase I Environmental Site Assessment (ESA) is being conducted in accordance with the pertinent procedures and limitations of the ASTM international (ASTM) Standards E 1527 – 05 and ER 1165-2-132, *Hazardous, Toxic, and Radioactive Waste Guidance for Civil Works Projects.*

This preliminary Phase I ESA process is limited to identifying known and suspected Hazardous, Toxic, and Radioactive Waste (HTRW) issues that may impact project decisions. After alternatives are decided, this Phase I ESA will be updated to account for a more detailed investigation of identified properties.

Although there are known, suspected, and potential HTRW release facilities identified, they do not indicate significant HTRW threats. The final conclusion is delayed until further investigations are made to property identified per alternative proposed.

Table of Contents

1.0 Introduction

1.1 Involved Parties

The U.S. Army Corps of Engineers - Seattle District (Corps) and the non-Federal Sponsors – the Skokomish Indian Tribe from here on referred to as the "Tribe" and Mason County are currently engaged in a General Investigation (GI) Feasibility Study (FS) for the Skokomish River basin located in the southwestern portion of Puget Sound in northwestern Washington, primarily in Mason County and the Skokomish Indian Reservation. The GI is a multi-purpose study intended to investigate ecosystem restoration and flood risk management improvements that will restore habitat for fish and wildlife species listed under the Endangered Species Act and provide structural and non-structural flood risk management measures on the Olympic peninsula near Shelton, Washington. The Corps signed a cost-sharing agreement with the Tribe and Mason County under the Corps' flood mitigation and ecosystem restoration authorities. The FS will result in a feasibility report integrated with an environmental impact statement (EIS) that will assess various alternatives and potential environmental impacts associated with the ecosystem restoration and flood risk management project.

1.2 Authority

The Skokomish River General Investigation GI/FS for the Skokomish River Basin is being conducted under the authority of Section 209 of the Flood Control Act of 1962.

1.3 Guidance and Policy

The Corps Engineering Regulation (ER) providing policy on Corps involvement in ecosystem restoration and protection through Civil Works programs and activities is contained in ER 1165-2-501 *Civil Works Ecosystem Restoration Policy.* Corps policy providing guidance for consideration of issues and problems associated with hazardous, toxic, and radioactive wastes (HTRW), as defined in this regulation, which may be located within project boundaries or may affect or be affected by Corps Civil Works projects is contained in ER 1165-2-132, *Hazardous, Toxic, and Radioactive Waste Guidance for Civil Works Projects*, which defines HTRW. ASTM International (ASTM) Standard E 1527-05 *Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process* provides a comprehensive guide for conducting a Phase I Environmental Site Assessment (ESA). These procedures are modified during the initial feasibility phase to allow the HTRW assessment to take into account the vastness of the study area and numerous property owners. This initial assessment is limited to the review of reasonable attainable environmental records. The assessment addresses the existence of, or potential for, HTRW contamination on lands, including structures and submerged lands in the study area, or external HTRW contamination which could impact, or be impacted by a project. Alternative project plans may consider avoidance of HTRW sites. At least one alternative plan should be formulated to avoid HTRW sites to the maximum extent possible, consistent with project objectives.

This initial assessment will help identify and develop the level of effort to be undertaken when alternatives are identified later in the feasibility phase. When alternatives are drafted, this document should be updated to include land use history, and type and extent of HTRW contamination found on identified properties, if any, and how HTRW considerations will impact the alternative project plans. Information to be used in the HTRW assessment of each alternative will be garnered from a visual site inspection of the potential project sites and nearby property and interviews with, current owners or managers and historical property owners if known, review of historic aerial photography and historical maps.

1.4 Scope of Work

The Skokomish River GI is a basin-wide study; however, work by others, constrain the limit of Corps' involvement to actions primarily in the lower Skokomish River Valley. Problems, opportunities, and objectives will be examined within the context of the entire watershed. Recognizing the relationships between the upper and lower watershed will ensure a comprehensive study overview. This preliminary HTRW assessment documents known and existing HTRW sites discovered through a search and review all reasonably attainable federal, state, and local government information and records. Other measures in the standards will be initiated after alternatives are identified. The investigation of each property per alternative proposed will involve analysis of historical media including historical aerial photographs and maps, a review of historical records, interviews, and visual site inspections of the properties. The complete investigation serves to identify any recognized environmental condition, as defined in ASTM Standard E 1527-05. This HTRW Phase I ESA will be updated to account for the individual property investigation of each of the alternatives.

1.5 Significant Assumptions

There are no significant assumptions during this preliminary HTRW Phase I ESA. Significant assumptions will be reevaluated during the site investigation of each alternative and this section will be updated accordingly.

1.6 Limitations and Exceptions

This preliminary HTRW Phase I ESA is limited to documenting known and existing HTRW sites to help in proposing alternatives. The limitations and exceptions will be reevaluated during the site investigation of each alternative and this section will be updated accordingly.

1.7 Special Terms and Conditions

No special terms or conditions significant with respect to ER 1165-2-132 and ASTM E 1527-05 standards were made.

1.8 User Reliance

In accordance with ASTM E 1527-05 Section 7.5.2.1 “Reliance,” the environmental professional is not required to independently verify the information provided by various sources but may rely on the information unless there is actual knowledge that certain information is incorrect or unless it is obvious that certain information is incorrect based on other information obtained during the course of the investigation or otherwise actually known to the investigators conducting the assessment. At the present time there is no indication that the information provided by the database search is incorrect. Future information collected as the project moves forward may be proven unreliable or may prove the unreliability of previously collected information. This report will be updated to document any unreliable information provided through outside sources.

2.0 Site Description

2.1 Location and Legal Description

The Skokomish River watershed covers approximately 240 square miles on the southeastern Olympic Peninsula and consists of three river sections which include the main stem of Skokomish River, the North Fork, and the South Fork. The North Fork originates in the northeastern section of the watershed where the majority of the river is diverted to Hood Canal by the Cushman Project. The South Fork originates in the southeastern section of the watershed in the Olympic Mountains, and drains an area of about 124 square miles. Flows of the South Fork are unregulated. With the Cushman Project diverting the majority of the North Fork flow, nearly all the flow of the main stem is fed by the South Fork. The main stem of the Skokomish River has a drainage of about 240 square miles and begins at the junction of the North and South Forks, about 9 miles upstream of Hood Canal. The main stem generally flows southeast and within the lower Skokomish River Valley where it flows through the Skokomish Indian Reservation into Annas Bay, Hood Canal.

Because the land being considered during this preliminary HTRW Phase I ESA is bound by drainage divides and does not depict real property, there is no legal description. Legal descriptions will be provided in the final HTRW PHASE I ESA when specific property is identified per alternative proposed during each site investigation.

2.2 Site and Vicinity General Characteristics

In general, the Skokomish area being considered for habitat restoration includes forested areas, agricultural areas, and private property. General characteristics, specific to property identified per alternative, will be described in detailed in the final HTRW PHASE I ESA.

2.3 Uses of the Property

General property uses of the Skokomish area being considered for this study include natural forest/river habitat, timberland, agricultural uses (hay production, cattle grazing, and other crops), private homeownership, and some small businesses. Agricultural, private homes with septic systems and businesses are all potentially a source of HTRW. A detailed description of current use of each property per alternatives proposed will be acquired during the site investigation of each alternative and documented in the final HTRW PHASE I ESA.

2.4 Uses of Adjoining Property

Property uses of adjoining property include those listed in previous section 2.3. Detailed descriptions of current uses of adjoining properties per alternatives proposed will documented in the final HTRW PHASE I ESA.

2.5 Descriptions of the Structures, Roads, Other Improvements on the Site

Detailed descriptions of structures, roads, and other improvements to property per alternative proposed will be documented the final HTRW Phase I ESA. Major Roads in the basin can be seen in Figure 1.

3.0 Records Review

3.1 Standard Environmental Records

Possible or known contaminated sites were by accessing Standard environmental record sources (electronic databases). The following list of sources was accessed on January 11, 2011.

- U.S. Environmental Protection Agency's EnviroMapper at <http://www.epa.gov/emefdata/em4ef.home>;
- Resource Conservation and Recovery Act (RCRAInfo)at <http://www.epa.gov/enviro/html/rcris/rcris_query_java.html>;
- Washington State Department of Ecology's Facilities Site Access at <http://apps.ecy.wa.gov/website/facsite/viewer.htm>; and
- Washington State Department of Ecology's Integrated Site Information System - Web Reporting (ISIS) databases at < https://fortress.wa.gov/ecy/tcpwebreporting/reports.aspx>

The standard environmental search results are displayed on Figure 1. Table 1 details the database search results by further describing the sites displayed on Figure 1.

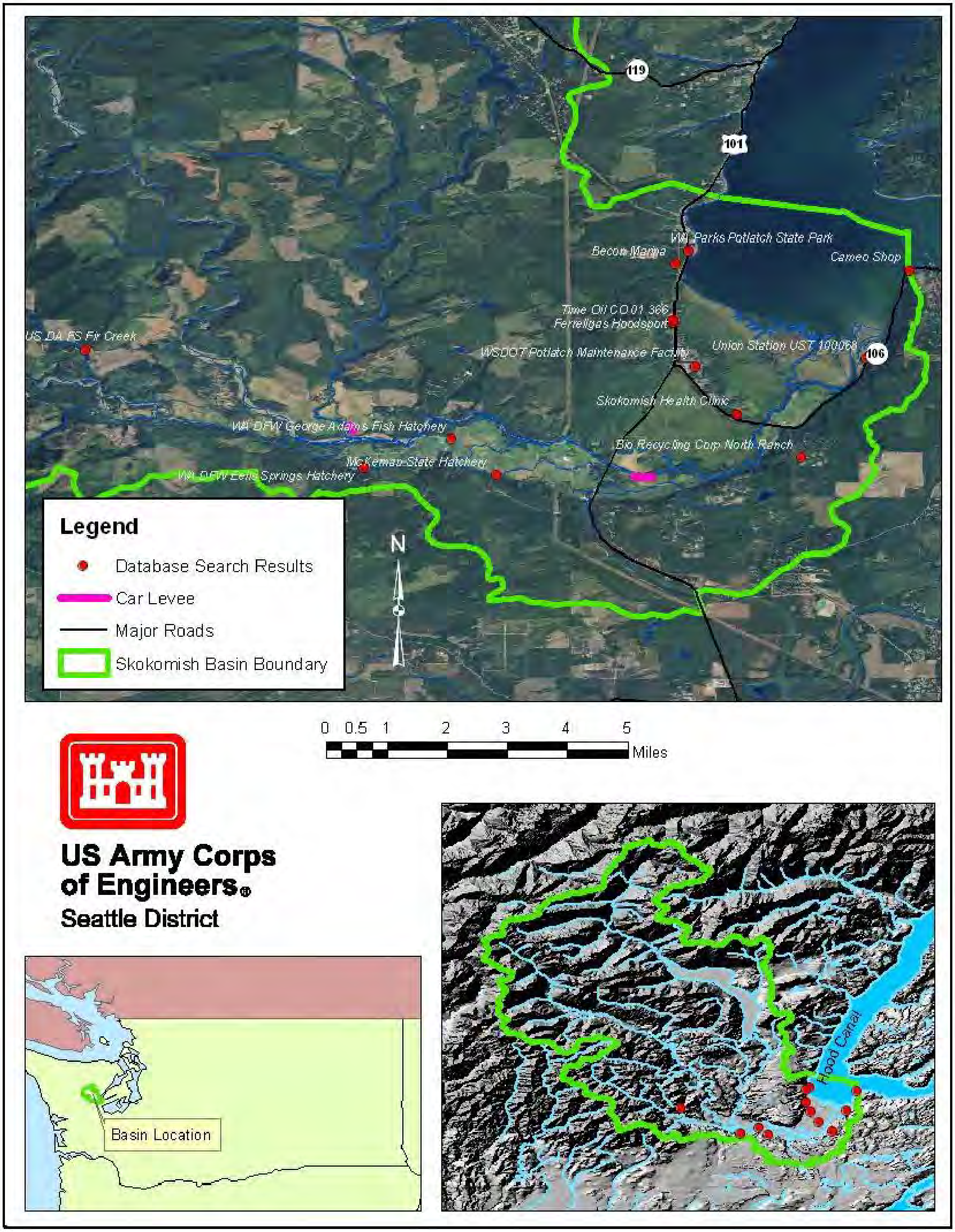

Figure 1 Facilities locations

Table 1 Facilities details

Name	***Address***	***Notes***
WA DFW George Adams Fish Hatchery	W 40 Skokomish Valley Rd. Shelton, WA 98584	Emergency/Haz Chem Rpt TIER2[1]; Hazardous Waste Generator - Conditionally Exempt small Quantity Generator; and Upland Fish Hatchery GP[2]
WA DFW Eells Springs Hatchery	7570 W. Eells Hill Rd. Shelton, WA 98584-9758	Emergency/Haz Chem Rpt TIER2[1] and Upland Fish Hatchery GP[2]
McKernan State Hatchery	411 W. Deyette Rd. Shelton, WA 98584-9760	UST LUST Facility: 1,000 gallon diesel tank was removed (1999) The site is currently awaiting cleanup. Upland Fish Hatchery GP[2]
WA Parks Potlatch State Park	N. 21020 HWY 101 Shelton, WA 98584	UST reported removed. No closure date recorded.
Union Station	E 4941 ½ HWY 106Union WA 98592	Closure in progress of three USTs.
Cameo Shop	6843 E. Hwy 106 Union, WA 98592	Three leaded gasoline USTs where removed. No closure date recorded.
Becon Marina AKA: CBM Sales Inc.	E 5561 Hwy 101 Union, WA 98592-0337	2 USTs (2,000 gal diesel and 1,500 gal leaded gasoline) removed. No closed date recorded.
Time Oil CO 01 366	N. 19930 Hwy 101 Shelton, WA 98584	Emergency/Haz Chem Rpt TIER2[1]
Ferrellgas Hoodsport	N. 19920 Hwy 101 Shelton WA, 98584	Emergency/Haz Chem Rpt TIER2[1]
Bio Recycling Corp North Ranch	820 E Webb Hill Rd. Union WA, 98592	Enforcement Final (Ecology Program W2R). An Enforcement action (i.e. Penalty, Order, Notice) was finalized, issued to the respective party, indicating the enforcement action was taken (2/10/2009; no end date recorded)
Skokomish Health Clinic	N 100 Tribal Center Road Shelton, WA 98584	RCRA Hazardous Waste Generator, Large Quantity Generator.
WSDOT Potlatch Maintenance Facility	Unknown Skokomish Indian Reservation	A Brownfields site in which a phase I assessment was completed in 2005. No further progress is reported.
US DA FS Fir Creek	T21N R5W S3, Hoodsport WA 98548	Hazardous Waste Generator, Large Quantity Generator

1 Businesses that store 10,000 pounds or more of a hazardous chemical or 500 pounds or less, depending on the chemical, of an extremely hazardous chemical on site at any one time must report annually. Reports are sent to the State Emergency Response Commission (represented by Washington State Department of Ecology) Local Emergency Planning Committees, and local fire departments for emergency planning (product, not waste).

2 General permits issued to operators of upland fin-fish hatching and rearing operations to regulate discharges to state waters.

3.2 User Provided Information

There is no user supplied information in this preliminary HTRW Phase I ESA. The Tribe or Mason County or both, depending on jurisdiction of property or properties, will provide the following information (3.2.1 thru 3.2.6) after properties are identified per alternatives proposed. This user provided information will assist in each site investigation and be presented in the final HTRW Phase I ESA.

3.2.1 Title Records

To be provided after properties are identified per alternative proposed.

3.2.2 Environmental Liens or Activity and Use Limitations

To be provided after properties are identified per alternative proposed.

3.2.3 Specialized Knowledge

To be provided after properties are identified per alternative proposed.

3.2.4 Commonly Known or Reasonably Ascertainable Information

To be provided after properties are identified per alternative proposed.

3.2.5 Valuation Reduction for Environmental Issues

To be provided after properties are identified per alternative proposed.

3.2.6 Owner, Property Manager, and Occupant Information

To be provided after properties are identified per alternative proposed.

3.3 Historical Records

3.3.1 Historic Photographs

After alternatives are drafted and properties identified, historic photographs including aerial photographs of each site will be obtained and analyzed for clues to past history of each alternative's site. The results will be presented in the final HTRW Phase I ESA.

3.3.2 Historic maps

After alternatives are drafted and properties identified, historic maps of each site will be obtained and analyzed for clues to past history of each alternative's site. These maps are to include historical United States Geological Survey (USGS) 7.5 minute maps. The results will be presented in the final HTRW Phase I ESA.

3.4 Additional Environmental Record Sources

There are no additional environmental record sources included in this preliminary HTRW Phase I ESA. Additional environmental record sources that can enhance and supplement the standard environmental record sources and meet the requirements of section 8.2.2 of the ASTM standards will be included in the final HTRW Phase I ESA.

4.0 Site Reconnaissance

Site reconnaissance was not performed for this preliminary HTRW Phase I ESA. The HTRW assessor will perform a site reconnaissance as part of the site investigation of each property per alternatives proposed. Site reconnaissance will be conducted per section 9 of ASTM E 1527 – 05.

4.1 Methodology and Limiting Conditions

Methodology and limiting condition for each alternative will be discussed in the final HTRW Phase I ESA.

4.2 General Site Setting

General site settings will be acquired through site reconnaissance during each site investigation and presented in the Final HTRW Phase I ESA.

4.3 Interior and Exterior Observations

Interior and exterior observations will be acquired through site reconnaissance during each site investigation and presented in the Final HTRW Phase I ESA.

4.4 Float Trip Observations (Summer 2010)

Members of the project team conducted a float trip through the main stem of the Skokomish River on 30 July 2010 (The HTRW assessor did not attend). The team noted two (2) car levees, made of junked automobiles placed alongside the river; 1) in the main stem approximately a half-mile east of Highway 101 and, 2) in the north fork, near the confluence with the main stem. These car levees are shown on the map in Figure 1. After alternatives are drafted, the car levees HTRW impact per alternative will be evaluated.

4.5 Interviews

Interviews have not been conducted during this preliminary HTRW Phase I ESA. Interviews per ASTM E 1527 – 05 standards will be conducted per alternative site. All interviews will be documented and summarized in the final HTRW Phase I.

5.0 Findings and Conclusion

Although there are known, suspected, and potential HTRW release facilities listed in Table 1, these facilities do not indicate significant HTRW threats. The known, suspected, and potential releases described in the table include underground storage tanks, storage of hazardous chemicals, known surface water discharges, and listings as hazardous waste facilities. There do not appear to be any significant or ongoing point sources. Non-point sources may include agricultural runoff to surface waters and residual contamination from the car levees. There does not appear to be any information indicating an impact from non-point sources on soil, surface water or sediment. The final conclusion is delayed until further investigations are made to property identified per alternative proposed.